UG Program Structure
[B.Tech: Mechanical Engineering]
Structure [M] Group

w.e.f A.Y. 2019-20 &applicable for batches admitted from A.Y. 2019-20 to 2022-23

[M- Group: Mechanical, Civil, Metallurgy & Material Science, Production S/W]

List of Abbreviations:

Abbreviation	Title	No of courses	Credits	% of Credits
BSC	Basic Science Course	9	27	16.3
ESC	Engineering Science Course	5	19	11.4
MLC	Mandatory Learning Course	4	0	0
SLC	Self-Learning Course	2	6 (Scheme A) 4 (Scheme B)	3.6
HSMC	Humanities/Social Sciences/Management Course	6	8	4.8
LLC	Liberal Learning Course	1	1	0.6
SBC	Skill Based Course	8	15 (Scheme A) 17 (Scheme B)	9.0
IFC	Interdisciplinary Foundation Course	2	4	2.5
IOC	Interdisciplinary Open Course	3	6	3.6
DEC	Department Elective Course	2	6	3.6
PCC	Program Core Course	19	56	33.8
LC	Laboratory Course	19	18	10.8

Semester III [M-Group]

Sr. No.	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	BSC		Ordinary Differential Equations and Multivariate Calculus And Linear Algebra and Univariate Calculus (for Students Directly admitted to S.Y. after Diploma)	2	1	0	3
2	BSC		Biology for Engineers	3	0	0	3
3	IFC		Industrial Electronics and Electrical Drive Systems (offered by Electrical Department)	2	0	0	2
4	SBC		Manufacturing Engineering - I Lab	0	0	2	1
5	PCC		Engineering Thermodynamics	3	0	0	3
6	PCC		Machine Drawing and Computer Graphics	2	0	0	2
7	PCC		Manufacturing Engineering-I	3	0	0	3
8	PCC		Strength of Materials	3	0	0	3
10	LC		Machine Drawing and Computer Graphics Lab	0	0	4	2
11	LC		Strength of Materials Lab	0	0	2	1
			Total	18	1	8	23
			Total Academic Engagement and Credits	**27**			**23**

Semester IV [M-Group]

Sr. No.	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	BSC		Vector Calculus and Partial Differential Equations And Multivariate Calculus and Differential Equations (for Students Directly admitted to S.Y. after Diploma)	2	1	0	3
2	MLC		Professional Laws, Ethics and Values	1	0	0	0
3	HSMC		Innovation and Creativity	1	0	0	1
4	IFC		Smart Materials (offered by Metallurgy Department)	2	0	0	2
5	PCC		Theory of Machines – I	3	0	0	3
6	PCC		Fluid Mechanics	3	0	0	3
7	PCC		Fundamentals of Metallurgy	2	0	0	2
8	PCC		Manufacturing process - II	3	0	0	3
9	LC		Rapid Prototyping Practice using Manufacturing process - II	0	0	2	1
10	LC		Fluid Mechanics Lab	0	0	2	1
11	LC		Fundamentals of Metallurgy Lab	0	0	2	1
12	LC		Theory of Machines Lab-I	0	0	2	1
			Total	17	1	10	22
			Total Academic Engagement and Credits	**28**			**22**

Semester III [M-Group]

(MA) ORDINARY DIFFERENTIAL EQUATIONS AND MULTIVARIATE CALCULUS

S.Y. B.Tech. Semester III (All Branches)

Teaching Scheme
Lectures : 2 hrs / week
Tutorials : 1 hr / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
Students will be able to

- Know and recall core knowledge of the syllabus. (To measure this outcome, questions may be of the type- define, identify, state, match, list, name etc.)
- Understand basic concepts. (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- Analyze the problem and apply the appropriate concept. (To measure this outcome, questions will be based on applications of core concepts)
- Give reasoning. (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, proving implications or corollaries of theorems, etc.)
- Apply core concepts to new situations. (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen passages.)

***Note:**
All the Course outcomes 1 to 3 will be judged by 75% of the questions and outcomes 4 and 5 will be judged by 25 % of questions.

Unit 1: (11 Hrs)
Review of first order differential equations, Reduction of order, linear differential equations, homogeneous higher order linear differential equations, non-homogeneous higher order linear differential equations with constant coefficients and reducible to differential equations with constant coefficients (method of undetermined coefficients and method of variation of parameters), systems of differential equations, applications to orthogonal trajectories, mass spring systems and electrical circuits.

Unit 2: (08 Hrs)
Laplace Transforms, its properties, Unit step function, Dirac delta functions, Convolution Theorem, periodic functions, solving differential equations using Laplace transform.

Unit 3: (07 Hrs)
Functions of several variables, level curves and level surfaces, partial and directional derivatives, differentiability, chain rule, local extreme values and saddle points, constrained optimization

Text Books:

- Thomas' Calculus (14^{th} edition) by Maurice D. Weir, Joel Hass, Frank R. Giordano, Pearson Education
- Advanced Engineering Mathematics (10^{th} edition) by Erwin Kreyszig, Wiley eastern Ltd.

Reference Books:

- Calculus for Scientists and Engineers by K.D Joshi, CRC Press.
- A Course in Multivariate Calculus and Analysis by SudhirGhorpade and BalmohanLimaye, Springer Science and Business Media.
- Differential Equations with Applications and Historical notes by George Simmons, Tata Mc-Graw Hill publishing company Ltd, New Delhi.

- Advanced Engineering Mathematics by C.R. Wylie, McGraw Hill Publications, New Delhi.
- Advanced Engineering Mathematics (7th edition) by Peter V. O' Neil, Thomson.Brooks / Cole, Singapore.
- Advanced Engineering Mathematics (2nd edition) by Michael D. Greenberg, Pearson Education.
- Advanced Engineering Mathematics by Chandrika Prasad and Reena Garg, Khanna Publishing Company Private Limited, New Delhi.

(MA) LINEAR ALGEBRA AND UNIVARIATE CALCULUS

S. Y. B.Tech. (for Students Directly admitted to S.Y. after their Diploma)

Teaching Scheme
Lectures : 4hrs / week
Tutorials : 1 hr / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
Students will be able to

- Know and recall core knowledge of the syllabus. (To measure this outcome, questions may be of the type- define, identify, state, match, list, name etc.)
- Understand basic concepts. (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- Analyze the problem and apply the appropriate concept. (To measure this outcome, questions will be based on applications of core concepts)
- Give reasoning. (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, proving implications or corollaries of theorems, etc.)
- Apply core concepts to new situations. (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen passages.)

***Note:**
All the Course outcomes 1 to 3 will be judged by 75% of the questions and outcomes 4 and 5 will be judged by 25 % of questions.

Unit 1: (15 Hrs)
Matrices and linear equations: basic properties of matrices, row operations and Gauss elimination, Determinants and their basic properties. Basic concepts in linear algebra: vector spaces, subspaces, linear independence and dependence of vectors, bases, dimensions. Rank of a matrix, Applications to systems of linear equations

Unit 2: (12 Hrs)
Rank-nullity theorem, Eigen values, Eigen vectors and their basic properties, diagonalization.

Unit 3: (12 Hrs)
Review of limits, continuity and differentiability, Mean value theorems, Taylor's theorem, local extrema, increasing and decreasing functions, concavity, points of inflection.

Unit 4: (13 Hrs)
Surface area, integrals by special techniques: reduction formulae, arc length, solids of revolution, improper integrals, tests for convergence, Gamma and Beta functions

Text Books:

- Thomas' Calculus (14th edition) by Maurice D. Weir, Joel Hass, Frank R. Giordano, Pearson Education.

- Advanced Engineering Mathematics (10th edition) by Erwin Kreyszig, Wiley eastern Ltd.

Reference Books:

- Introduction to Linear Algebra (2nd edition) by Serge Lang, Springer.
- Elementary Linear Algebra (10th edition) by Howard Anton and Chris Rorres, John Wiley and sons.
- Calculus for Scientists and Engineers by K.D Joshi, CRC Press.
- A Course in Calculus and Real Analysis (1st edition) by SudhirGhorpade and BalmohanLimaye, Springer-Verlag, New York.
- Advanced Engineering Mathematics by C.R. Wylie, McGraw Hill Publications, New Delhi.
- Advanced Engineering Mathematics (7thedition) by Peter V. O' Neil, Thomson.Brooks / Cole, Singapore.
- Differential Calculus by Shanti Narayan, S. Chand and company, New Delhi.
- Applied Mathematics Vol. I (Reprint July 2014) by P.N. Wartikar and J.N. Wartikar, Pune VidyarthiGrihaPrakashan Pune.
- Advanced Engineering Mathematics by Chandrika Prasad and Reena Garg, Khanna Publishing Company Private Limited, New Delhi.

() BIOLOGYFORENGINEERS

Teaching Scheme
Lectures : 3 hrs / week

Examination Scheme
Internal Test 1 (Classroom activity): 20 marks
Internal Test 2 (Assignments): 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
Students will be able to

- To understand basic biological principles and Organizational structure of Living systems at molecular level
- To understand basic biological principles and Organizational structure of Living systems at cellular and system level
- To understand Energy transformations in biological systems
- To understand Information processing in Biological systems
- To understand biological process with engineering perspective
- To impart knowledge about the common corridors of biology and engineering and biologically inspired technologies

Unit 1: (06Hrs)
Biomolecules and biopolymers:
Structure and Function: Organic and inorganic molecules; Unique Properties of water, Vitamins and Minerals, Carbohydrates, Lipids, Amino Acids and proteins, Nucleic Acids (DNA and RNA)

Unit 2:(06Hrs)
Levels of organization of life: Evolution of multi-cellularity, Cell as a basic unit of life, prokaryotic and eukaryotic cells, microbes, plant and animal cells; Cell organelles – structure and function; Cell membrane
Levels of organization: cells, tissues, organs, systems & organism

Unit 3:(06Hrs)
Energy transformations in Cholorplast: Photosynthesis (photochemical & biochemical phase) and ATP generation Aerobic and anaerobic systems
Energy transformations in Mitochondria: Cellular respiration (glycolysis and Kreb cycle) and ATP generation

Bioenergetics: Thermodynamic principles applied to biology, negative entropy changes in biological systems, Free Energy, Chemical Equilibrium

Unit 4:(06Hrs)
Expression and Transmission of Genetic Information
DNA replication: Enzyme driven processof DNA cloning
Protein synthesis: Transcription & translation
Techniques for optimization:
At molecular level: Recombinant DNA Technology, DNA hybridization, PCR, DNA microarray

Unit 5: (06Hrs)
Transport Phenomena in Biological Systems: Membrane channels and ion channels; Fluid flow and mass transfer (nutrients & ions)

- In plants: Xylem and Phloem
- In animals: Blood and Lymph
- Transport of gases: Oxygen and Carbon dioxide
- Heat Transport - Body temperature regulation.

Communication: Cell junctions, Cell-cell communications – cell signaling, Hormones, Pheromones and cell behavior
Defense mechanisms in plants and animals:

- In plants: Herbivory, secondary metabolites
- In animals: Innate and Adaptive immune systems

Unit 6: (06Hrs) Engineering perspectives of biological sciences:
Biology and engineering crosstalk –
At cell level: Hybridoma technology
At tissue level: Plant Tissue Culture, Animal Tissue Culture;
Tissue Engineering: Principles, methods and applications
Introduction to Biomimetics and Biomimicry, nanobiotechnology

Reference Books:

- Lodish H, Berk A, Zipursky SL, et al. (2000) Molecular Cell Biology. W. H. Freeman.
- Lehninger, A. L., Nelson, D. L., & Cox, M. M. (2000). *Lehninger principles of biochemistry*. New York: Worth Publishers.
- Rao CNR, et.al. Chemistry of Nanomaterials: Synthesis, Properties and Applications.
- Eggins BR. (1006) Biosensors: An Introduction. John Wiley & Sons Publishers.
- Palsson B.O. and Bhatia S.N. (2009) Tissue Engineering. Pearson.
- Yoseph Bar-Cohen (2005). Biomimetics- Biologically Inspired Technologies
- Joseph D. Bronzino, John Enderle, Susan M. Blanchard (1999) Introduction to Biomedical Engineering.
- Routledge Taylor and Francis group (2012). Introduction to Bio-medical Engineeering technologies

Table 1.2: Additional topics to be discussed with students (in branch-wise manner)

Understanding various diseases/ disorders with respect to the physiology, diagnosis, therapeutics (biomaterials and instrumentation) and medical procedures e.g. Cardiovascular, Renal, Aurthopedic etc.

Disease/ Disorder	Physiology	Diagnosis	Therapeutics		Medical procedure
			Biomaterials	Instrumentation	
Cardiovascular disease	Heart – electrical stimulation and mechanical	ECG, Angiography	Stents for angioplasty	Heart lung machines	Angioplasty, By-pass surgery

	pumping				
Bone/skull injuries	Biomechanics of musculo-skeletal system	Medical imaging technologies Arthroscopy	Prosthetics	Arthroscope Biomechanics Prosthetics	Joint replacement Total hip replacementrehabilitati-on engg
Kidney disorders	Functioning of Kidney	Medical imaging technologies	Filtration membranes	Dialyser	Dialysis

(EE) INDUSTRIAL ELECTRONICS AND ELECTRICAL DRIVE SYSTEMS

Teaching Scheme
Practical : 2 hrs / week

Examination Scheme
Term work: 50 marks
Practical/Oral: 50 marks

Course Outcomes:
Student will be able to:

- Select a suitable power electronics converter for various industrial applications.
- Choose appropriate IC for various industrial applications.
- Use a right sensor for various industrial applications.
- Evaluate and analyze the parameters, operating characteristics and performance of various motors.
- Study various electrical machines and their applications in for appropriate application.

Unit 1: (5hrs)
Power Electronics Devices and Converters
Power control devices, their characteristics, protection and applications: SCR, Triac, Power MOSFET, IGBT. Triggering circuits using Diac/UJT and digital logic.Light dimmers and fan regulators, controlled rectifiers.Basics of DC to DC and DC to AC convertors, UPS.

Unit 2: (5hrs)
Integrated Circuits and Applications
Op-Amp IC 741, audio power Op-Amp, wave form generator (square and ramp), Schmidt trigger, IC 555 as mono-stable and astable multi vibrator, sequential timers, cascading of timers, adder, sub tractor, shift registers, counters, opto isolators and opto couplers. Applications in mechanical engineering such as staircase, traffic light, lift controller.

Unit 3: (5hrs)
Industrial Devices and Applications
Smoke, temperature, pressure, vibrations, displacement, flow, level detectors, proximity switches, controllers using sensors.Analog to digital and digital to analog converters, introduction to PLC, concept of distributed control systems, concept of computerized numerical controllers. Resistance welding, RF heating energy storage welding, ultrasonic method of testing of materials, principles of LASER and applications, CRO as a display device for industrial application, electronic weighing systems, electronic ignition systems.

Unit 4: (5hrs)
DC Machines and Drives
Construction of DC machines, armature and field systems, types.Generator operation: emf equation, characteristics and applications, armature reaction, commutation process, losses and efficiency.Motor operation: back emf, torque equation, characteristics, starting, speed control, braking, losses and efficiency, selection of motors for various applications.Basic DC motors drives systems: operation and applications.

Unit 5: **(5hrs)**

Induction Motor, Special Motors and Drives

Three phase induction motor construction, revolving magnetic field, motoring operation, types, circuit model, no load and on load operation, power output, torque developed, torque- speed characteristic, speed control, starting and braking, losses and efficiency, applications, induction generator principle.Basic induction motor drives systems: operation and applications.Working principle, construction, characteristics, speed control and applications (descriptive treatment only) of single phase induction motors. Working principle, construction, characteristics, speed control and applications (descriptive treatment only) of stepper motors, servomotors, hysteresis motors, and reluctance motors, AC series motors and universal motors.

Unit 6: **(5hrs)**

Synchronous Machines and Drives

Three-phase synchronous machines: construction, different types, principle of operation, emf equation, synchronous reactance, equivalent circuit, voltage regulation and efficiency, motoring and generating operation, power and torque expressions, V and inverted V characteristics of synchronous motors, starting, braking and speed control, regulation of an alternator.Basic synchronous motor drives systems: operation and applications.Selection and applications of electrical drives, selection of power rating based on thermal limits, over load and load variation factors for industrial applications like rolling mills, cranes, winches, traction, shear press, mechanical press, power mills, textile industry, coal and mining industry.

Reference Books:

- Industrial Electronics: Chute & Chute: Electronics in Industry, Tata McGraw Hill.
- R.P. Jain: Modern Digital Electronics, Tata McGraw Hill.
- Ramamoorthy: Thyrister and Power Electronics Applications, Prentice Hall of India.
- Harish C. Rai: Industrial and Power Electronics (Umesh Publication, Delhi).
- C. S. Rangan, Sharma, Mahi: Instrumentation, devices and system (WIE).
- Curtis Johnson: Process Instrumentation, Prentice Hall of India. Electrical Drive Systems:
- Pillai S. K.: First course in Electrical Drives – Wiley Eastern.

(ME) MANUFACTURING ENGINEERING – I LABORATORY

Teaching Scheme
Practical : 2 hrs / week

Examination Scheme
Term work: 50 marks
Practical/Oral: 50 marks

Course Outcomes:

At the end of the course, students should be able to:

- Get the knowledge of working of machine tools, mechanisms and accessories used in various manufacturing processes.
- Perform the job of turning, chamfering, taper turning and threading operation using lathe.
- Perform Welding using gas/arc/ resistance welding process.

Term work:

Each candidate shall be required to complete and submit the following term work:

Jobs:

Plain and Taper turning – one job
Thread cutting – one Job
Welding (gas or arc or resistance) – one job

Journal:

Assignments on machine tools will be in the form of a journal based on demonstrations on machine tools. This should include sketches and relevant descriptions as given below:

1) Machines (Any Two)
   a) Lathe,
   b) Universal milling machine,
   c) Radial drilling machine,
   d) Cylindrical grinder.

2) Mechanisms (Any Two)
   a) Capstan & Turret lathe,
   b) Spindle arbor (assembly) drive of milling machine,
   c) Crank and slotted lever quick return drive of shaping machine,
   d) Shaper quick return mechanism.

3) Accessories (Any Two)
   a) Universal dividing head,
   b) Milling cutter.

(ME) ENGINEERING THERMODYNAMICS

Teaching Scheme
Lectures : 3 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
Students will be able to

- Apply basic laws of thermodynamics in analysis and design of thermodynamic cycles including vapor and gas power cycles, refrigeration cycles, and heat-pump.
- Use thermodynamic relations in evaluation of thermodynamic properties.
- Apply the fundamentals of conservation of mass and energy, and properties of ideal gas mixtures in design and analysis
- Enhance problem solving skills.
- Evaluate performance of air standard cycles
- Gain design skills in thermal systems and enhance written communication.

Unit 1: (5hrs)
Basic concepts and properties
Introduction, thermodynamic system, control volume, macroscopic and microscopic approaches, properties and state of a system, point and path functions, thermodynamic equilibrium, processes and cycles, quasi-static process, properties such as specific volume, pressure, temperature, zeroth law of thermodynamics, temperature scales.

Unit 2: (6hrs)
Ideal gases and vapors
Difference between gases and vapors, ideal gases, gas laws, equation of state, gas constant, universal gas constant, work and heat, definition of work, thermodynamic work, work in compressible system, work-a path function, work done during various processes, p-v diagram, definition of heat, heat transfer a path function, comparison of heat and work, Phase change process of a pure substance: specific heats, sensible heat and latent heat, triple point, critical point, superheat and total heat of steam.

Unit 3: (6hrs)
First law of thermodynamics
Energy of systems, classification of energy, law of conservation of energy, first law applied to closed system undergoing a cycle, Joule experiment, energy-a property of system, internal energy: a function of temperature, enthalpy, specific heat at constant volume and constant

pressure, change in internal energy and heat transfer during various non-flow processes. First law applied to flow processes: steady state steady flow process, mass balance and energy balance in steady flow process, steady flow energy equation and its application to nozzles and diffusers, throttling valve, turbines and compressors, pumps, heat exchangers etc. Work done and heat transfer during steady flow processes.

Unit 4: (7hrs)

Second law of thermodynamics

Limitations of first law, heat engines, refrigerators and heat pumps, Kelvin-plank and Clausius statements, their equivalence, reversible and irreversible processes, factors that render processes irreversible, Carnot cycle, two propositions regarding the efficiency of Carnot cycles, the thermodynamic temperature scale, reversed Carnot cycle, COP of heat pump and refrigeration. Thermodynamic processes – constant volume, isothermal, adiabatic, polytropic processes, throttling and free expansion- p-v and T-s diagrams-work done, heat exchanged, change in internal energy.

Unit 5: (6hrs)

Entropy

Inequality of Clausius, entropy: a property of system, entropy change for ideal gases, entropy change of a system during irreversible process, lost work, principle of increase of entropy. Availability and irreversibility: available energy referred to cycle, decrease in available energy with heat transfer through a finite temperature differences. T-ds equations, Availability in a steady flow system, irreversibility and effectiveness.

Unit 6: (8hrs)

Power cycles: Gas power cycles

Otto cycle, Diesel cycle, semi-Diesel, Sterling cycles, their efficiency and mean effective pressure calculations. Vapors power cycles: Properties of steam, specific volume and entropy of steam, dryness fraction of steam, throttling of steam, determination of dryness fraction, steam tables and their use, T-s and H-s diagram, Rankine and modified Rankine cycle, work done and efficiency, specific steam consumption, comparison of Rankine and Carnot cycle, representation on P-v, T-s and h-s diagram.

Text Books

- Thermodynamics: An Engineering Approach, 3rd Edition, YunusÇengel and Michael, Boles, Tata McGraw Hill.
- Basic and Applied Thermodynamics, 2nd Edition, Nag P. K., Tata McGraw-Hill.

Reference Books

- Fundamentals of Thermodynamics, 5th Edition, Richard E. Songtag, Claus Borgnakke and Gordon J. Van Wylen, John Wiley and Sons, Inc.
- Thermodynamics, 4th Edition, J.P. Holman, McGraw-Hill.Engineering Thermodynamics, 2nd Edition, Jones J.B. and Hawkins G.A., John Wyley and Sons.
- Fundamentals of Engineering Thermodynamics, Moran M.S. and Shapiro H.N., John Wyley andSons, 1988.
- Thermodynamics, 5th Edition, K. Wark, McGraw-Hill

(ME) MACHINE DRAWING AND COMPUTER GRAPHICS

Teaching Scheme
Lectures : 2 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:

Students will be able to

- Demonstrate the knowledge of various ISO standards production drawing practices.
- Develop and interpret production drawings using various standards, symbols, tolerances, limits and fits.
- Effectively communicate drawing using software like AutoCAD and AutoLISP.

Unit 1: **(6hrs)**

Introduction to Machine Drawing

Types of Drawings, Production Drawing, Assembly and part drawings, Blue print reading, Study and preparation of bill of materials. Dimensioning Techniques, Representation of all types of standard components, Riveted & Welded Joints, Locking Arrangements. Conventional representation of piping layouts, pipe fittings, valves, joints. Stuffing box & glands, Expansion joints.

Unit 2: **(6hrs)**

Limits, Fits and Tolerances

ISO system of tolerance, Tolerance charts, Hole - base and shaft -base system of tolerance, Types of fits, symbols and applications, values related to various manufacturing processes.

Unit 3: **(6hrs)**

Geometric Tolerances and Surface Roughness

Geometric Tolerances:Introduction, Nomenclature, Rules, Symbols, datums and applications of Geometric Tolerances, Max & Min Material principles, Positional Tolerancing.

Surface Roughness & ProductionDrawing: Surface Textures, Roughness values and Roughness Grades, Machining symbols Conventional Representation on part drawings.

Unit 4: **(4hrs)**

Basic Drafting commands

Drawing basic entities, Modify commands, Edit commands … etc , Layers , Block attributes, Viewers, Design center utilities , Solid Modelling – Part Modeling& Assembly Modeling , Editing of solids, 3-D operations such as shading and rendering etc.

Unit 5: **(4hrs)**

Introduction to CAD programming

Concept of parametric programming, Need and importance of CAD programming. Data types: Integers, Real numbers, Strings, Symbols, Lists and File Descriptors. Data types conversions: Integer to real, string list, real to integer, string lists. Reading and writing to the screen by using visual lisp consoles.

Unit 6: **(6hrs)**

Functions and Tools of CAD Programming

Inputs in CAD Programming: Get functions for user input. Use of lists and the entities: Filtering from lists, editing/ modifying the lists, entity managing and modifying the entities. Arithmetic and Logical Functions: Additions, Subtraction, Multiplication, Division, sorting the data for deciding maximum and minimum numbers, remainders, exponential operation, trigonometric functions, AND, OR etc. Decision-making and looping, File handling functions (changing the properties of AutoCAD entities). Block attributes and extracting the attribute data.

Text Books:

- K. L. Narayana, P. Kanniah, & K.V. Reddy, “Machine Drawing ”, SciTech Publications (India Pvt. Ltd.) Chennai

Reference Books:

- IS Code: SP 46 – 1988, Standard Drawing Practices for Engineering Institutes
- Auto CAD &Autolisp Manuals by AutoDesk Corp., USA
- “Design Data”, Faculty of Mechanical Engineering, PSG College of Tech, Coimbatore

- N.D.Bhatt and P.Kanniah, “Machine Drawing”, Charotar Pub. House, Anand, Gujrath
- S. Trymbaka Murthy, “Computer Aided Engineering Drawing”, I.K. International Publishing House Pvt. Ltd, Pune

(ME) MANUFACTURING ENGINEERING – I

Teaching Scheme
Lectures : 3 hrs / week

Examination Scheme
Assignments /Quiz:40 marks
End Sem. Exam: 60 marks

Course Outcomes:
Students should be able to

- Identify and explain the function of the basic components of machine tools and its accessories
- Analyse various machining processes and select the particular manufacturing process for a given job.
- Have the knowledge of casting and forming process and solve the casting and forming problems.
- Explain various surface treatment processes and its engineering applications.

Unit 1: (8hrs)
Hot and cold working of metals
Principles ofrolling, forging, drop, press, upset, roll forging, extrusion, drawing, spinning, and effect of hot working. Cold working processes**,** Cold rolling, swaging, forging, extrusion- forward, backwardand impact roll forming, tube drawing, wire drawing, spinning, shot penning, high energy rate forming, sheet metal working, types of presses, drives, different operations and types of dies, Forging design**.**

Unit 2: (6hrs)
Joining processes
Arc welding- Theory, SMAW, GTAW, GMAW, FCAW, Submerged arc welding, Stud welding Resistance welding- Theory, spot and seam projection welding processes Gas welding Friction welding, Ultrasonic welding, Thermit welding, EBW and LASER welding Use of adhesive for joining, classification of adhesives, types of adhesive and their application, surface preparation and various joints welding defects and quality.

Unit 3: (8hrs)
Foundry- Pattern making, moulding and casting
Sand casting, types of pattern material, pattern making allowances, core print moulding, sand properties and testing, hand and machine moulding, core boxes, core making, melting and pouring, melting furnaces- Cupola, electric arc and induction furnaces. Cleaning, finishing and heat treatment of casting, defects in casting, shell moulding and investment casting. Permanent mould dies casting- Die-casting, low-pressure permanent mould casting, hot and cold chamber processing, centrifugal casting, semi centrifugal casting and continuous casting.

Unit 4: (8hrs)
Turning, drilling and reaming
Turning and boring, lathe construction, accessories and operations. Thread cutting- single and multi-start threading, concept of speed, feed and depth of cut. Capstan and Turret lathe. Fundamentals of drilling processes, drill geometry, types of drilling machines, operations performed on drilling machines, type of drill. Reaming processes and reamer types.

Unit 5: (7hrs)
Milling, shaping and planning

Fundamental aspects, cutter types and geometry, Operations performed on milling machine, dividing head method of indexing. Construction, working and operations performed on shaper, planer, and broaching machines.

Unit 6: **(5hrs)**

Grinding

Grinding wheels, wheel marking, wheel selection, wheel mounting and types of grinding machines. Honing, lapping, super finishing, buffing and burnishing processes.

Text Books:

- Chapman W.A.-"Workshop Technology, Vol. II, III, & I", Edward Arnold Pub.Ltd. London
- HajraChaudhary S.K.- Elements of Workshop Technology, Vol. I& II, Media Prom & Pub, Mumbai.

Reference Books:

- HMT Hand book- Production Technology
- Roy A. &Linberg- "Processes and materials of manufacturing", Prentice Hall of India Delhi.
- Campbell J.S.: Principles of manufacturing Materials and Processes, McGraw-Hill, New York.
- Begeman - "Manufacturing processes", Asia Publishing house Bombay.

(CE)STRENGTH OF MATERIALS

Teaching Scheme
Lectures : 3 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:

Students should be able to:

- Apply basic concepts in mechanics to solve various problems.
- Determine the types of stresses developed in statically determinate member due to different actions.
- Analyze various problems in engineering applications subjected to various actions.

Unit 1: **(7hrs)**

Simple stresses and strains

a. Concept of stress and strain (linear, lateral, shear and volumetric) Hooks law. Elastic constants and their relationship. Generalized Hook's law.

b. Axial force diagram, stresses, strains and deformation in determinate and indeterminate homogeneous and composite bars under concentrated loads, self-weight and temperature changes.

Unit 2: **(7hrs)**

a. Shear force and bending moment diagrams
Concept and definition of shear force and Bending Moment in beams due to concentrated load, UDL, uniformly varying loads and couples in determinate beams. Relation between SF, BM and intensity of loading, SF, and BM diagrams for cantilevers, simple compound beams and bend.

b. Stresses due to bending

Theory of simple bending, concept and assumptions, Derivation of Flexure formula. Bending stress distribution diagram. Moment of resistance and section modulus calculations.

Unit 3: (6hrs)

a. Shear stress distribution in beams

Shear stresses concept, derivation of shear stress distribution formulae, shear stress distribution diagram for common symmetrical sections, maximum and average shear stress

b. Torsion of circular shaft

Theory of torsion of shafts of circular, cross section. Assumptions, Derivation of torsion formulae, stresses and strains in determinate and indeterminate shafts of hollow, solid, homogeneous circular cross section subjected to twisting moments, stresses due to combine torsion, bending.

Unit 4: (6hrs)

a. Principal stresses and principal strain

Normal and shear stresses on any oblique planes and concept of principal planes and principal stresses by analytical and graphical methods (Mohr's circle of stress 2-D).

b. Pressure Vessels

Stresses, strains and deformation in thin walled seamless cylindrical and spherical vessels due to internal fluid pressure. Change in volume, effects of additional fluid injected under pressure.

Unit 5: (5hrs)

Slope and Deflection of Determinate Beams

a. Concept and definition, relation between B.M., slope and deflection slope and deflection by double integration method (McCauley's method).

b. Slope and Deflection in determinate beams by Moment Area method

Unit 6: (5hrs)

a. Axially loaded columns

Concept of critical load and buckling, derivation of Euler's formulae for buckling load with hinged ends, concept of equivalent length for various end conditions. Rankine's formulae, safe load on column, Limitations of Euler's formulae.

b. Strain energy and impact

Concept of strain energy, derivation and use of expressions for deformation of axially loaded members under gradual sudden and impact loads.

Text Books:

- Ramamurtham Strength of Materials DhanpatRaiPublcation
- S.S. Rattan-Strength of Materials, Tata McGraw Hill Publication CO.Ltd.S

Reference Books:

- Mechanics of Materials" By R.C.Hibbeler (6th Edition) Pearson Education
- "Introduction to Mechanics of Solids" by J.B. Popov, Prentice – Hall publication
- "Mechanics of Materials" by James M.Gere (5th Edition) Brooks/Cole Thomson Learning.
- "Strength of Material" by F. L. Singer and Pytel, Harper and Row publication
- "Mechanics of Material" by Beer and Johnston, McGraw Hill publication

(ME) MACHINE DRAWING AND COMPUTER GRAPHICS LABORATORY

Teaching Scheme
Practical : 4 hrs / week

Examination Scheme
Term work: 50 marks
Practical/Oral: 50 marks

Course Outcomes:
Students will be able to:

- Select appropriate limits, fits and tolerances for manufacturing of machine elements.
- Demonstrate use of surface finish, standard symbols and abbreviation on production drawing.
- Apply knowledge of production drawing for development of part and assembly drawing by manual and computer assisted drafting.

Term work:
Machine Drawing

1. One full imperial drawing sheet consisting the drawing/ sketches of representation of standard components, symbols of pipe joints, weld joints, rivet joint etc, surface finish symbols & grades, Limit, fit and tolerance related sketches.
2. One full imperial drawing sheet consisting of assembly and details of any one standard component such as valves, components of various machine tools, pumps etc.

CAD Drawing and Programmes

1.Assignment of CAD drawings

a. Simple Orthographic Views, Orthographic Projections with three views of any one simple machine component such as bracket, Bearing Housing or Cast component for Engines such as Connecting rod, Piston etc. and its' 3-D model.
b. Isometric Views of machine components
c. Part Modeling, Assembly Modeling and Automated Drafting

2.Assignments of CAD programming

1. Introductory programmes (minimum two on each) such as
   a. Programmes to draw geometric figure or their combinations with changes in the type of input required, for those figures. Such programmes should have use of arithmetic functions, data conversions, filtering from lists.
   b. Programmes to draw figures using Data type conversion involving users input data, blinking on the screen use of trigonometry for solving graphics problems etc.
2. Parametric Programming (minimum two on each) such as
   a. Program to draw a standard machine component by using decision-making and looping statement of Autolisp.
   b. Program to draw a profile, generated after getting data from user such as profile of cam, profile of gear tooth, profile of points present on moving links or mechanisms etc.
3. Programme to enhance the capacity of CAD drawing
   a. Making the File handling programmes
   b. Obtaining animation of moving parts or mechanisms
   c. Changing the Front page / display by Menu Customization Programme.
4. Innovative programmes: Innovative programme of any type, by using Autolisp environment

(CE) STRENGTH OF MATERIALS LABORATORY

Teaching Scheme
Practical : 2 hrs / week

Examination Scheme
Term work: 50 marks
Practical/Oral: 50 marks

Course Outcomes:
Students will be able to:

- Effectively utilize the knowledge obtained in theory in order to perform practical.

- Understand the effect of tensile, shearing force and can utilize the knowledge gained while tackling real life engineering problems.
- Effectively incorporate the important concepts learnt while designing components.

List of Experiments:

1. Tension test on Mild Steel and Aluminum
2. Shear test on Mild Steel and Aluminum
3. Torsion test on Mild Steel and Cast-Iron
4. Impact test on Mild Steel, Aluminum and Cast-Iron
5. Hardness test on Mild Steel, Aluminum and Cast iron
6. Bending test on Timber, Plywood and Mild Steel.

Semester IV [M-Group]

(MA) Vector Calculus and Partial Differential Equations

Teaching Scheme
Lectures : 2 hrs / week
Tutorials : 1 hr / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:

Students will be able to:

- Know and recall core knowledge of the syllabus. (To measure this outcome, questions may be of the type- define, identify, state, match, list, name etc.)
- Understand basic concepts. (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- Analyze the problem and apply the appropriate concept. (To measure this outcome, questions will be based on applications of core concepts)
- Give reasoning. (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, proving implications or corollaries of theorems, etc.)
- apply core concepts to new situations. (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen passages.)

***Note:**

All the Course outcomes 1 to 3 will be judged by 75% of the questions and outcomes 4 and 5 will be judged by 25 % of questions.

Unit 1: (10 Hrs)

Double integrals in Cartesian and polar co-ordinates, iterated integrals, change of variables, triple integrals in Cartesian, spherical and cylindrical co-ordinates, substitutions in multiple integrals, Applications to Area, Volume, Moments and Centerof Mass.

Unit 2: (07 Hrs)

Vector differentiation, gradient, divergence and curl, line and surface integrals, path independence, statements and illustrations of theorems of Green, Stokes and Gauss, arc length parameterization, applications.

Unit 3: (09 Hrs)

Partial differential equations with separation of variables, boundary value problems: vibrations of a string, heat equation, potential equation, vibrations of circular membranes.

Text Books:

- Thomas' Calculus (14th edition) by Maurice D. Weir, Joel Hass, Frank R. Giordano, Pearson Education.
- Advanced Engineering Mathematics (10th edition) by Erwin Kreyszig, Wiley eastern Ltd.

Reference Books:

- Advanced Engineering Mathematics by C.R. Wylie, McGraw Hill Publications, New Delhi.
- Functions of several variables by Wendell Fleming, Springer-Verlag, New York.
- Partial Differential Equations (4th edition) by Fritz John, Springer.
- Advanced Engineering Mathematics (7th edition) by Peter V. O' Neil, Thomson.Brooks / Cole, Singapore.
- Advanced Engineering Mathematics (2nd edition) by Michael D. Greenberg, Pearson Education.
- Advanced Engineering Mathematics by Chandrika Prasad and Reena Garg, Khanna Publishing Company Private Limited, New Delhi.

(MA) Multivariate Calculus and Differential Equations

(for Students Directly admitted to S.Y. after their Diploma)

Teaching Scheme
Lectures : 4 hrs / week
Tutorials : 1 hr / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:

Students will be able to:

- Know and recall core knowledge of the syllabus. (To measure this outcome, questions may be of the type- define, identify, state, match, list, name etc.)
- Understand basic concepts. (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- Analyze the problem and apply the appropriate concept. (To measure this outcome, questions will be based on applications of core concepts)
- Give reasoning. (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, proving implications or corollaries of theorems, etc.)
- Apply core concepts to new situations. (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen passages.)

***Note:**

All the Course outcomes 1 to 3 will be judged by 75% of the questions and outcomes 4 and 5 will be judged by 25 % of questions.

Unit 1: (09 Hrs)

Review of first order differential equations, linear differential equations, homogeneous higher order linear differential equations, non-homogeneous higher order linear differential equations with constant coefficients (method of undetermined coefficients and method of variation of parameters).

Unit 2: (07 Hrs)

Laplace Transforms, its properties, Unit step function, Dirac delta functions, Convolution Theorem, periodic functions, solving differential equations using Laplace transform.

Unit 3: (07 Hrs)

Functions of several variables, level curves and level surfaces, partial and directional derivatives, differentiability, chain rule, local extreme values and saddle points

Unit 4: **(12 Hrs)**

Double integrals in Cartesian and polar co-ordinates, iterated integrals, change of variables, triple integrals in Cartesian, spherical and cylindrical co-ordinates.

Unit 5: **(10 Hrs)**

Vector differentiation, gradient, divergence and curl, line and surface integrals, path independence, statements and illustrations of theorems of Green, Stokes and Gauss

Unit 6: **(07 Hrs)**

Partial differential equations with separation of variables, boundary value problems: vibrations of a string, one dimensional heat equation.

Text Books:

- Thomas' Calculus (14th edition) by Maurice D. Weir, Joel Hass, Frank R. Giordano, Pearson Education.
- Advanced Engineering Mathematics (10th edition) by Erwin Kreyszig, Wiley eastern Ltd.

Reference Books:

- Calculus for Scientists and Engineers by K.D Joshi, CRC Press.
- A Course in Multivariate Calculus and Analysis by SudhirGhorpade and BalmohanLimaye, Springer Science and Business Media.
- Differential Equations with Applications and Historical notes by George Simmons, Tata Mc-Graw Hill publishing company Ltd, New Delhi.
- Functions of several variables by Wendell Fleming, Springer-Verlag, New York.
- Partial Differential Equations (4th edition) by Fritz John, Springer.
- Advanced Engineering Mathematics by C.R. Wylie, McGraw Hill Publications, New Delhi.
- Advanced Engineering Mathematics (7th edition) by Peter V. O' Neil, Thomson.Brooks / Cole, Singapore.
- Advanced Engineering Mathematics (2nd edition) by Michael D. Greenberg, Pearson Education.
- Advanced Engineering Mathematics by Chandrika Prasad and Reena Garg, Khanna Publishing Company Private Limited, New Delhi

(MLC) Professional Laws, Ethics, Values & HarmonyAudit Course

Teaching Scheme
Lectures : 1 hrs / week

Examination Scheme
Total - 100 Marks
Continuous evaluation:
Assignments/Presentations/Tes

Course Outcomes:

Student will be able to:

- grasp the meaning of the concept - Law
- get an overview of the laws relating to Engineers
- apprehend the importance of being a law abiding person
- self-explore by using different techniques to live in harmony at various levels
- analyze themselves and understand their position with respect to the moral and ethical character needed for a successful and satisfactory work life

Unit 1: **(02 Hrs)**

Concept of Law

Understanding Essentials of a Valid Contract and the basics of contract law protecting rights and obligations

Unit 2: **(03 Hrs)**

Law of Torts

Introduction to the Law of Torts and the basics to protect oneself and the company Law affecting the Workplace Employers Responsibilities / Duties Hiring Practices Introduction to Intellectual Property Law

Unit 3: **(01 Hrs)**

Professional Code of Conduct for Engineers, Relationship between Law and Ethics

Unit 4: **(02 Hrs)**

Self-Awareness

Understanding oneself and others; Johari Window- Concept, explanation, implementation

Unit 5: **(02 Hrs)**

Needs & Self

Needs and its importance; Understanding harmony and its relevance in actualization at personal and professional levels

Unit 6: **(02 Hrs)**

Ethics and values

Professional ethics and their importance for students; Understanding the importance ofvalues & their application in everyday life

References

- Business Law- By Saroj Kumar
- Law of Contract- By Avtar Singh
- Business Law- By G K Kapoor
- Business & Commercial Laws – By Sen&Mitra
- Business Law for Engineers- by Calvin Frank Allen
- Hilgard, E. R.; Atkinson, R. C. & Atkinson, R.L. (1975). Introduction to Psychology. 6th Edition. New Delhi: Oxford and IBH Publishing Co. Pvt. Ltd.
- Govindarajan, M; Natarajan, G. M. &Senthilkumar, V.S. (2013). Professional Ethics & Human Values. Prentice Hall: New Delhi
- Gogate, S. B. (2011). Human Values & Professional Ethics. Vikas Publishing: New Delhi.
- Govindarajan, M; Natarajan, G. M. &Senthilkumar, V.S. (2013). Professional Ethics & Human Values. Prentice Hall: New Delhi
- Jayshree Suresh, Raghavan B.S. (2016). Human Values & Professional Ethics: S Chand &Company.Pvt.Ltd: New Delhi.

(MT) SMART MATERIALS

Teaching Scheme
Lectures : 3 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:

Student will be able to:

- Introduce students to the concept of “Smart” materials and systems.
- Inculcate knowledge of various smart materials, their fabrication and their multidisciplinary applications.

Unit 1: **(05Hrs)**

Concept of Smart Materials: Retrospective review, main notion, energy aspects of external influence, systematization and methods of smart materials description: methods of materials taxonomy, smart material model, classification of smart materials and engineering systems.

Unit 2: (05 Hrs)

Materials for electrical engineering and electronics: conductors, semiconductors, dielectrics, magnetic materials, optically active materials, materials for thermoelectric devices, smart battery materials, radio wave absorbing materials, sealing materials, heat-insulating and sound absorbing materials

Unit 3: (05 Hrs)

Structural materials: self-healing materials, heat and cold resistant materials, radiation resistant materials, corrosion-resistant materials and anti-corrosive coatings, lubricants, frictional materials, materials for operation at abnormal temperatures

Unit 4: (05 Hrs)

Materials for biological and biomedical systems: materials for implants, targeted drug delivery and tissue growth, antimicrobial materials, filters for water cleaning, biodegradable packages, active and bio-selective packages

Unit 5: (07Hrs)

Mechanics of smart materials: Object and subject of smart materials mechanics, structural and functional analysis smart materials in terms of mechanics, the materials with negative characteristics as source of smart effects in structures: Auxetics, statements and solutions of some smart materials based mechanics problems – e.g. self-healing of cracks, self-reinforcing of multimodular materials, porous materials-auxetic materials reversible transformations, self-assembling porous materials etc.

Unit 6: (03Hrs)

Smart materials and energy problem: Global energy problem, energy consumption for production of materials, technical and economic efficiency of smart materials and technical systems

Text Books:

- Smart Materials Taxonomy by Victor Goldade, Serge Shil'ko, Alexander Neverov, CRC Press, 1st Edition, 2016
- Smart Electronic Materials by Jasprit Singh, Cambridge University Press, 1st Edition, 2005
- Smart Materials Systems and MEMS: Design and Development methodologies by Vijay K. Varadan, K.J. Vinoy, S. Gopalkrishnan, John Wiley and Sons, 1st Edition, 2006

Reference Books:

- Encyclopedia of Smart Materials (Volume 1 and 2) by Mel Schwartz, John Wiley and Sons, 1st Edition, 2002
- Smaert Materials Edited by Mel Schwartz, CRC Press, 1st Edition, 2009
- Design, Fabrication Properties and Applications of Smart and Advanced Materials, Edited by XuHou, CRC Press, 1st Edition, 2016
- Smart Materials: Integrated Design, Engineering Approaches and Potential Applications, Edited by AncaFilimon, Apple Academic Press and CRC Press, 1st Edition, 2019

(ME) THEORY OF MACHINES - I

Teaching Scheme

Lectures : 3 hrs / week

Examination Scheme

Internal Test 1: 20 marks

Internal Test 2: 20 marks

End Sem. Exam: 60 marks

Course Outcomes:

Student will be able to:

- Determine kinematic analysis (Velocity, acceleration, Inertia forces) for a given of a given mechanism using analytically and graphically method.
- Demonstrate the dynamics of cams and followers, governors, and their characteristics.
- Draw inversions and determine velocity and acceleration of different mechanisms.
- Construct different types of cam profile for a given data.
- Solve and determine forces and dimensions of Spur and Helical Gear.
- Calculate speeds and study performance of various types of Gyroscope.

Unit 1: (08 Hrs)

Fundamentals of kinematics and mechanisms:

Kinematic link, Types of links, Kinematic pair, Types of constrained motions, Types of Kinematic pairs, Kinematic chain, Types of joints, Mechanism, Machine, Degree of freedom (Mobility), Kutzbachcrieterion, Grubler's criterion, Inversion, Four bar chain and its inversions, Grashoff's law, Slider crank chain and its inversions, Double slider crank chain and its inversions, steering gear mechanisms, Hooke's joint, Introduction to Compliant mechanism.

Unit 2: (12 Hrs)

Velocity and acceleration analysis:

Relative velocity acceleration methods, Corioli's component of acceleration, instantaneous center of Rotation method, Kennedy theorem of three center in line, body and space centrode, Klein's construction, Position analysis of links with vector and complex algebra methods, Velocity and acceleration analysis of mechanisms using vector and complex algebra methods. Synthesis of Mechanisms

Unit 3: (08 Hrs)

Static and dynamic force analysis of slider crank mechanism:

Analytical method for displacement, velocity and acceleration of slider crank mechanism, D'Alembert's principle, static and dynamic force analysis of slider crank mechanism, dynamically equivalent system, correction couple, graphical and analytical method for determination of torque on crankshaft.

Unit 4: (08 Hrs)

Theory of Gears I:

Classification of gears, Types of gears, Spur gears - terminology, fundamental law of toothed gearing, involute and cycloidal profile, conjugate action, contact ratio, minimum number of teeth, interference and under cutting. Helical gears: Nomenclatures, center distance, force analysis.

Unit 5: (06 Hrs)

Cams and followers:

Types of cams and followers, types of follower motion, velocity and acceleration diagrams, profile of cam cams with specified contours.

Unit 6: (06 Hrs)

Governor Mechanisms:

Introduction, Types- Mechanical and Electronic, Governor Effort and governor power, Controlling force analysis, sensitivity, stability, isochronisms and hunting, friction, insensitiveness

Text Books:

- Ballaney, P., "Theory if Machines and Mechanisms", 2005, ISBN 9788174091222 / 817409122X Khanna Publications

- John Hannah and Stephens, R. C., “Mechanics of Machines: Advanced Theory and Examples”, 1970, Hodder; Student international edition, ISBN 0713132329 Edward Arnold London

Reference Books:

- UickerJr, J. J., Penock G. R. and Shigley, J. E., “Theory oif Machines and Mechanisms’ 2003, Tata McGraw Hill.
- Ramamurthy V., “Mechanisms of Machines”, 3rd edition, ISBN 978-1842654569,Narosa Publishing House.
- Bevan Thomas, “The Theory of Machines”, 3rd edition, CBS publication.
- Bansal, R. K., “Theory of machines”, Laxmi Publications Pvt. Ltd, New Delhi

(ME) FLUID MECHANICS

Teaching Scheme
Lectures : 3 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
Students should be able to:

- Understand and apply the basic concepts of Fluid Mechanics.
- Derive analytical solutions to variety of simplified problems.
- Solve problems involving fluid properties: Static and kinematic.
- Derive and apply the governing equations of Fluid Dynamics.
- Apply energy equations for various Fluid systems and measuring devices.
- Apply and understand various dimensionless numbers for problems in fluid mechanics

Unit 1: (08 Hrs)

Basics with fluid statics:

Definition of fluid, fluid properties such as viscosity, vapor pressure, compressibility, surface tension, capillarity, Mach number etc, pressure at a point in the static mass of fluid, variation of pressure, Pascal’s law, pressure measurement by simple and differential manometers using manometric expression.

Hydrostatic forces on the plane and curved surfaces, centre of pressure, Buoyancy, centre of buoyancy, stability of floating bodies, metacentre and metacentric height and its application in shipping

Unit 2: (06 hrs)

Fluid Kinematics:

Velocity of fluid particle, types of fluid flow, description of flow, continuity equation, acceleration of fluid particle, rotational & irrotational flow, path line, stream line and streak line Laplace’s equation in velocity potential and Poisson’s equation in stream function, flow net, Vorticity and Circulation.

Unit 3: (06 hrs)

Governing equations in Fluid Dynamics:

Derivation of Momentum equations using differential approach (Cartesian, polar and cylindrical coordinates), Reynolds transport theorem, Integration of Euler’s equation to obtain Bernoulli’s equation, Bernoulli’s theorem, Application of Bernoulli’s theorem such as Venturimeter, Orifice meter, pitot tube (static , dynamic and stagnation pressure) and orifices etc. Introduction to NavierStokes Equation.

Unit 4: (06 hrs)

Flow through pipes:

Reynolds's experiment, frictional loss in pipe flow, major and minor losses, HGL and TEL, flow through series and parallel pipes, Equivalent Pipe, Loss of head due to friction in a pipe with side tappings, siphon, Power Transmission, Pipe networks . Moody's Diagram.

Unit 5 **(06 hrs)**

Introduction to boundary layer: Thickness, over a plate, Equations of boundary layer, Laminar and turbulent boundary layer, introduction to flow separation of layer, and methods for control. Introduction to Forces on Submerged bodies: Drag, lift, Drag on cylinder, Development of lift in Cylinder. Dimensional homogeneity, Rayleigh's method, Buckingham's theorem. Similitude and Model analysis: similarity laws and dimensionless numbers.

Unit 6 **(06 hrs)**

Laminar flow: Hagen-Poiseuillie equation, flow through parallel plates, Couette flow.
Turbulent flow: Development in pipes, Velocity distribution in pipes, hydrodynamic smooth and rough pipe.

Text Books:

- Hydraulics and Fluid Mechanics including Hydraulic Machines, Dr. P. N. Modi and Dr. S. M. Seth, Standard Book House .
- Text book of Fluid Mechanics and Hydraulic Machine, Dr. R. K.Bansal, Laxmi Publications, New Delhi.
- Fluid Mechanics – Fundamentals and application. YunusCengel and John Cimbala
- Introduction to Fluid Mechanics and Fluid Machines. S. K.Som, GautamBiswas and SumanCharaborty. Mc-Graw Hill Publication

Reference Books:

- Introduction to Fluid Mechanics . Fox R W, Pritchard P J, A T Mc Donald. John Wiley and Sons Publication.
- Fluid Mechanics, Frank M. White. McGraw Hill Publications.
- Engineering Fluid Mechanics, Prof K L Kumar, Chand Publication.
- Fluid Mechanics, P. K. Kundu , I. M. Kohen and David Dowling Fifth Edition Elsevier Publication.

(ME) FUNDAMENTALS OF METALLURGY

Teaching Scheme
Lectures : 3 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
Student will be able to:

- Demonstrate an understanding of the structure-property-processing correlation engineering materials.
- Select appropriate EV materials for various mechanical aspects.
- Suggest suitable types of steels and cast irons as per required application.
- Propose appropriate heat treatment for various metals and alloys studied for a particular application.
- Able to understand the concept of powder metallurgy and its application

Unit 1: **(06 Hrs)**

Engineering Materials

Overview of Metallic Materials: Ferrous, Non Ferrous Metals and their alloys (Al, Cu, Bearing Material: important properties and applications), Ceramics- Traditional and Engineering Ceramics, Polymers: Traditional and Special Polymers, Composites: Ceramic- Metal- Polymer

composites, Carbon nano tube composites, Nanomaterials and its importance in nanoscale (m.p., electrical conductivity, strength).

Unit 2: **(08 Hrs)**

Plain Carbon and Alloy Steels

Type of equilibrium diagrams in metals and alloys, lever rule. Iron - Carbon equilibrium diagram, critical temperatures. Allotropy, cooling curve and volume changes of pure iron. Microstructures of slowly cooled steels, estimation of carbon from Microstructures, non-equilibrium cooling of steels, Effects of alloying elements and examples of alloy steels. Stainless steels. Tool steels and tool materials. Applications of plain carbon and alloy steels, specifications of some commonly used steels for engineering applications (e.g. En, DIN, IS etc with examples)

Unit 3: **(08 Hrs)**

Heat Treatment of Steels

Transformation products of austenite, Time temperature Transformation diagrams, Critical cooling rate, continuous cooling transformation diagrams. Heat treatment of steels, Cooling media. Annealing, normalizing, hardening. Tempering, Carburising, Nitriding, carbonitriding, Flame and Induction hardening. Commercial heat treatment practice of gears of different sizes, tools, lathe beds, springs, etc.

Unit 4: **(06 Hrs)**

Cast Irons

Classification of Cast irons Gray cast irons, nodular cast irons, white cast irons, malleable cast irons, chilled. Effect of various parameters on structure and properties of cast irons. Applications of cast irons for different components of machine tools, automobiles, pumps, etc.

Unit 5: **(08 Hrs)**

Materials for EVs

Introduction to e-vehicles and their classification, Comparison with the IC Engine Technology, e-vehicles life cycle analysis and raw material availability, Economic considerations for batteries in e-vehicles, Value chain for electric car batteries, Introduction to various Li ion battery, super capacitors, fuel-cells and various battery technologies. Comparative study of energy and power density of various battery technologies. Critical Metals for electric motors: Nd, Eu, Y, Tb, Dy; rare earth magnets for electric motors, rare-earth free magnets, and their comparative studies.Structural materials for EVs: fibre reinforced composites, steels, Al etc., Materials required in charging stations

Unit 6: **(06 Hrs)**

Powder Metallurgy

Sintered structural components, Advantages and Limitations of powder metallurgy, powder manufacture, testing and characterization, Manufacturing of typical P/M products : cemented carbides, cermets, sintered carbide cutting tools, diamond impregnated tools , sintered metal friction materials and self-lubricating bearings. Introduction to hot and cold working.

Text Books:

- D. R. Askland& P. P. Phule, “Material Science & Engineering of Materials”, by Cengage Learning Center India Pvt Ltd. , Sixth Indian Edition, 2011
- R. A. Higgins, Engineering Metallurgy Part-I, Applied Physical Metallurgy, ELBS with Edward Arnold, Sixth Edition 1993.
- S.H. Avner, Introduction to Physical Metallurgy , Tata Mac Graw Hill, Second edition, 1997.
- Richard Folkson, Alternative fuels and advanced vehicle technologies for improved environmental performance: Towards zero carbon transportation, Woodhead Publishing, 1st Edition, 2014

- M. Ehsani, Y. Gao, S. Longo, K. Ebrahimi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles, CRC Press, 3rd Edition, 2018

Reference Books:

- V. Raghvan, "Materials Science & Engineering", PHI 5th Edition, Prentice-Hall of India (P) Ltd.
- W. Callister, "Materials Science & Engineering", John Wiley & sons
- Clark D. S. and Varney W. R., "Physical Metallurgy for Engineers", Affiliated East-West Press, New Delhi.
- R. Balasubramaniam ,Callister's Materials Science and Engineering, Wiley India Pvt Ltd., 2008.
- K. Bhargava and C. P. Sharma, Mechanical Behaviour and Testing of Materials, Publication PHI 2011

(ME) MANUFACTURING ENGINEERING - II

Teaching Scheme
Lectures : 3 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course outcome:
Students will be able to:

- Demonstrate various non-conventional manufacturing processes and select proper process for the purpose of manufacturing.
- Develop competency for selecting appropriate machining process depending on desired output characteristics such as MRR, surface finish.
- Select proper machine tool for economic production.

Unit 1: (07 Hrs)
Sheet metal working
Introduction to sheet metal working, press-types and main parts of power press, die details and accessories, metal cutting in a punch and die set up, die details and accessories, types of dies, clearance, angular clearance, various press operations, strip layout, centre of pressure, cutting forces, methods of reducing cutting forces, Blanking die design, drawing- blank size calculations, number of draws, drawing force, Bending- Bend allowance, bending force calculations

Unit 2: (07 Hrs)
Theory of metal cutting
Mechanics of chip formation, oblique and orthogonal cutting, single point tool geometry, types of chips, cutting ratio, shear plane angle, velocities in cutting, Merchant circle, shear strain, power in cutting, cutting tool materials, cutting fluid, machinability, evaluation of machinability, optimum cutting speed, tool life, factors affecting tool life, computation of tool life.

Unit 3: (06 Hrs)
Non-conventional methods of machining
Need of nonconventional methods of machining, classification of non-conventional methods of machining, Operating principle, process parameters, advantages, disadvantages and applications of any four non-conventional methods of machining which uses different forms of energy.

Unit 4: (07 Hrs)
Jigs and fixtures
Introduction to jigs and fixtures, need, 3-2-1 principle of location, various locating devices, cavity location, redundancy in location, fool proofing, clamping devices, general guidelines for

design of jig/fixtures. Design of jig for simple component, design of milling fixture for simple component.

Unit 5:

NC, CNC, DNC (04 Hrs)

Introduction to CAD/CAM, NC-Basic components, procedure, coordinate system, motion control, applications, merits and problems, CNC-types, functions and advantages, DNC- Types, functions and advantages. Introduction to adaptive control, FMS and machining centre.

Surface treatment processes (03 Hrs)

Introduction to surface engineering, surface structure and properties, surface texture, need of surface treatment processes, various types of surface treatment processes, Introduction to any four surface treatment processes such as peening, burnishing, heat treatment etc.

Unit 6:

Broaching (03 Hrs)

Broach-geometry/elements, principle, Types of broaching machines, comparison of broaching with other processes, applications, broach design.

Gear manufacturing(03 Hrs)

Gear manufacturing by forming processes, gear generating processes such as gear shaping, hobbing, milling, hobbing, Gear finishing processes- shaving, roll finishing, grinding, lapping

Text Books:

- Chapman, “Workshop technology” Vol. I, II & III; Edward Arnold Publications Ltd. London.
- HajaraChaudhary S. K., “Workshop Technology” Vol. I & II, Media Prom & Publication, Mumbai.
- R. K. Jain, “Production Technology”; Khanna Publications
- Hoffman, “Introduction to Jigs and fixtures”, Galgotia Publishers

Reference Books:

- S. K. Basu, “Fundamentals of Tool design”, Tata Mcgraw Hill Education Private limited.
- SeropeKalpakjian& Steven R. Schmid, “Manufacturing processes for engineering materials
- HMT Hand book “Production technology”, Tata Mcgraw Hill Education Pvt. Ltd.
- S. E. Rusinoff, “Manufacturing processes”, Times India Press.
- Doyle, “Manufacturing processes and materials for engineers”, Prentice Hall of India Press

(ME) Manufacturing Engineering- II laboratory

Teaching Scheme
Practical : 2 hrs / week

Examination Scheme
Term work: 50 marks
Practical/Oral: 50 marks

Course Outcomes:

Students should be able to:

- Use different Non-Conventional processes for the given applications.
- Perform job on CNC machine by using CNC programming.
- Use manufacturing machine tools and make the given jobs.
- Design the Jigs and Fixture for the given jobs.

Term-work:

Each candidate shall be required to complete and submit the following term work.

Part A

1. One composite job consisting of at least one spur gear to be made by each student.
2. One composite Job on CNC Lathe/Milling which includes operations like Turning, Facing, Taper Turning, Drilling etc.

Part B

1. Demonstration on different non-conventional machining set-ups to manufacture simple components.
2. Demonstrations on different surface treatment processes.

Part C

A journal consisting of:

1. Design of a jig or fixture. (No fabrication).
2. Assignments on NC/CNC Machines, Press working, Non-conventional processes, Advanced manufacturing Processes etc.

(ME)FLUID MECHANICS LABORATORY

Teaching Scheme
Practical : 2 hrs / week

Examination Scheme
Term work: 50 marks
Practical/Oral: 50 marks

Course Outcomes:

Student will be able to:

- Measure the pressure using manometers
- determine the forces experienced by the body when flow occurs around it
- carry out the velocity measurement using pitot tube
- determine the coefficient of discharge using Bernoulli's equation
- determine the friction factor for flow

Term-work:

The candidates have to carry out the experiments and the analysis of the fluid flow phenomenon through at least 8 experiments from the following

1. Measurement of viscosity using Red Wood viscometer
2. Study and demonstration of pressure measurement using manometers
3. Determination of the metacentric height of a floating body and its stability
4. Demonstration of electrical analogy method for flow measurement
5. Determination of coefficient of discharge for Venturi meter
6. Determination of coefficient of discharge for orifice meter
7. Determination of coefficient of discharge for rectangular notch
8. Demonstration of Pitot tube for velocity measurement
9. Determination of the friction factor for flow through a long circular pipe
10. Determination of pressure variation around a circular body when it is submerged in a flow

(MT) FUNDAMENTALS OF METALLURGY LABORATORY

Teaching Scheme
Practical : 2 hrs / week

Examination Scheme
Term work: 50 marks
Practical/Oral: 50 marks

Course Outcomes:

Students will be able to:

- Perform mechanical tests on metallic materials.
- Perform heat treatment on steels.
- Distinguish between microstructures of various metallic materials.

Term-work:

1. To perform hardness test on different metallic samples.
2. 2.To perform tensile test on different metallic samples.

3. To perform Impact test on different metallic samples.
4. Non-Destructive tests: Magnaflux testing, Dye penetrant testing.
5. Study and drawing of microstructures of various types' plain carbon steel.
6. To perform various types of heat treatment on plain carbon steels.
7. To study effect of heat treatment on microstructure and hardness of plain carbon steel.
8. Study and drawing of microstructures of various types cast irons.

(ME) THEORY OF MACHINES– I LABORATORY

Teaching Scheme
Practical : 2 hrs / week

Examination Scheme
Term work: 50 marks
Practical/Oral: 50 marks

Course Outcomes:

- Students will demonstrate knowledge of various mechanisms in order to design and analyze mechanisms essential in mechanical engineering.
- Students will demonstrate ability towards graphically estimating velocity and acceleration.
- Students will exhibit skills towards application of principles of static and dynamics force analysis.
- Knowledge attained will comply towards successfully addressing issues relating to gears, governors, cams and followers in real life engineering problems.

List of Experiments:

1. Determination of moment of inertia of rigid bodies by bifilar/trifilar suspension methods.
2. Determination of moment of inertia of Compound pendulum.
3. Experimental verification of displacement relation for different shaft angles for single Hooke's joint.
4. To generate gear tooth profile and to study the effect of under cutting and rack shift using model.
5. To determine the characteristics curve of any two type of centrifugal governor and to find its coefficient of insensitiveness and stability.

List of Assignments:

1. Velocity and acceleration by vector and complex algebra method
2. Analytical determination of inertia forces in engine mechanisms.
3. Problem on steering gear mechanism.

List of Drawing Sheets:

1. Graphical solution to problems on velocity acceleration in mechanism by relative velocity and acceleration method including problem with Corioli's component of acceleration.
2. Velocity by instantaneous center method.
3. Klein's construction and inertia force analysis for slider cranks mechanisms.
4. To draw cam profile for various types of followers motion.

College of Engineering, Pune

(An Autonomous Institute of Govt. of Maharashtra, Permanently Affiliated to S.P. Pune University)

Department of Mechanical Engineering

Curriculum Structure & Detailed Syllabus (UG Program)

Third Year B. Tech.

(Effective from: A.Y. 2021-22)

Program Education Objectives (PEOs):

I. Cater to the needs of Indian as well as multinational industries

II. Be competent with strong technological background to analyze data, formulate and undertake industrial problems and obtain viable solutions

III. Make successful career in industry / research / higher Studies

IV. Be life-long learning and should be able to work on multi-disciplinary projects

V. Be Competent for effective communication, in management and in professional skills and ethics

Program Outcomes (POs):

On successful completion Graduates will demonstrate:

1. Engineering knowledge
2. Problem analysis
3. Design/development of solutions
4. Conduct investigations of complex problems
5. Modern tool usage
6. The engineer and society
7. Environment and sustainability
8. Ethics
9. Individual and team work
10. Communication
11. Project management and finance
12. Life-long learning

Correlation between the PEOs and the POs

PO→ PEO↓	1	2	3	4	5	6	7	8	9	10	11	12	PSO1	PSO2	PSO3
I	✓		✓		✓	✓	✓				✓		✓		✓
II	✓	✓	✓		✓								✓		
III				✓		✓		✓	✓			✓		✓	✓
IV		✓	✓		✓					✓	✓	✓	✓	✓	✓
V						✓		✓	✓	✓	✓				✓

Programme Specific Objectives (PSOs):

I. Apply concepts of Design, Production and Thermal-fluid sciences to solve engineering problems utilizing advanced technology.

II. Use mechanical engineering software for the design and analysis of mechanical engineering systems/processes.

III. Extend and implement new thoughts on product design and development with the aids of modern CFD and CAD/CAM/CAE tools, while ensuring best manufacturing practices.

List of Abbreviations

Sr. No.	Abbreviation	Stands for:
1	BSC	Basic Science Course
2	DEC	Department Elective Course
3	HSMC	Humanities, Social Sciences including Management courses
4	IFC	Interdisciplinary Foundation Course
5	IOC	Interdisciplinary Open Course
6	LC	Laboratory Course
7	MLC	Mandatory Learning Course
8	PCC	Program Core Course
9	SBC	Skill Based Course

CURRICULUM STRUCTURE OF T. Y. B.TECH (Mechanical)

Effective from A. Y. 2021-2022

V-Semester:

Sr. No	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	BSC	MA-21001	Probability and Statistics for Engineers	2	1	0	3
2	MLC	ML-21002	Environmental Studies	1	0	0	0
3	IFC	CT (IF)-21001	Interdisciplinary Foundation Course–III Data Analytics	1	0	2	2
4	HSMC	AS (HS)-	Humanities & Social Sciences Open Course -II	2	0	0	2
		21005	Industrial Psychology				
		21006	Personal Psychology				
		21007	Engineering Economics				
		21008	Finance for Engineers				
5	SBC	ME-21008	Skill Based Course of the Domain: Design of Machine Components	0	0	2	1
6	PCC	ME-21001	Fluid Machinery and Fluid Power	3	1	0	4
7	PCC	ME-21002	Metrology and Mechanical Measurements	3	0	0	3
8	PCC	ME-21003	Heat Transfer	3	0	0	3
9	PCC	ME-21004	Design of Machine Components	3	1	0	4
10	LC	ME-21005	Fluid Machinery and Fluid Power Lab	0	0	2	1
11	LC	ME-21006	Metrology and Mechanical Measurements Lab	0	0	2	1
12	LC	ME-21007	Heat Transfer Lab	0	0	2	1
			Total	**18**	**03**	**10**	**25**
			Total Academic Engagement and Credits	**31**			**25**

Minor and Honor courses (V-Semester)

Sr. No.	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	Minor in Product Design and Optimization	ME (MI)-21001	Product Design	3	0	0	3
2	Honor in Hybrid and Electric vehicle	ME (HO)-21001	Automotive Engineering Systems	3	0	0	3
3	Honor in Thermal Stream	ME (HO)-21002	Fluid Dynamics	3	0	0	3
4	Honor in Design Stream	ME (HO)-21003	Comprehensive Design	3	0	0	3

VI-Semester:

Sr. No.	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	MLC	ML-21001	Constitution of India	1	0	0	0
2	HSMC	AS (HS)-	Humanities & Social Sciences Open Course - I	2	0	0	2
		21001	English Proficiency Language				
		21002	German Language				
		21003	Japanese Language				
		21004	Spanish Language				
3	HSMC	HS-21001	Entrepreneurship Principles and Process	1	0	0	1
4	SBC	ME-21016	Mini Project ["D-S-P-T: Design-Simulate-Prototype-Test "]	0	0	4	2
5	IOC	Shown in IOC / DE list	Interdisciplinary Open Course-I	2	0	0	2
6	DEC		Department Elective-I/ Industry Floated Course / Co-Taught Course	3	0	0	3
7	PCC	ME-21009	Computational Methods & Programming	2	0	0	2
8	PCC	ME-21010	Theory and Design of Mechanical Systems	3	1	0	4
9	PCC	ME-21011	Steam and Gas Turbine	3	0	0	3
10	PCC	ME-21012	Fuels and Combustion	3	0	0	3
11	LC	ME-21013	Computational Methods & Programming Lab	0	0	2	1
12	LC	ME-21014	Theory and Design of Mechanical Systems Lab	0	0	2	1
13	LC	ME-21015	Steam & Gas Turbine And Combustion Lab	0	0	2	1
			Total	**20**	**1**	**10**	**25**
			Total Academic Engagement and Credits	**31**			**25**

Minor and Honor courses (VI Sem)

Sr. No.	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	Minor: Product Design and Optimization	ME (MI)-21002	Engineering Design	3	0	0	3
2	Honors: Hybrid and Electric vehicle	ME (HO)-21004	Automotive Mechatronics	3	0	0	3
3	Honor in Thermal Stream	ME (HO)-21005	Micro fluidics	3	0	0	3
4	Honor in Design Stream	ME (HO)-21006	Fracture mechanics	3	0	0	3

List of Departmental Electives:

Sr. No.	Course Code	Elective Course	Sr. No.	Course Code	Elective Course
1	ME (DE)-21001	Computational Fluid Dynamics and Heat Transfer	5	ME (DE)-21005	Mathematical Modeling and Analysis of Thermal System
2	ME (DE)-21002	Steam Technology	6	ME (DE)-21006	Micro Electro Mechanical Systems
3	ME (DE)-21003	Advanced Manufacturing Technology	7	ME (DE)-21007	Finite Element Analysis
4	ME (DE)-21004	Operations Research			

Interdisciplinary Open Course-I (IOC)

Sr. No.	Course Code	Course Name
01	IOC-21005	Renewable Energy (Offered by Mechanical Engineering Department)

MA 21001 Probability and Statistics for Engineers

Teaching scheme
Lectures: 2 hrs/week
Tutorial: 1 hr/week

Examination Scheme
Internal Test 1: 20 Marks
Internal Test 2: 20 Marks
End – Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Demonstrate number of methods of summarizing and visualizing data sets, evaluate probabilities of events.
- Make use of concepts of random variables and associated probability distributions to solve problems, illustrate the central limit theorem.
- Test for basic statistical inference (t-test, z-test, F-test, $\chi 2$ –test, confidence interval, non parametric tests).
- Explain basic principles of regression analysis and perform the same.
- Demonstrate use of R software for all the above.

Unit 1 **(5 hrs)**

Descriptive statistics: Measures of location and variation. Visualization of data: Frequency tables, bar diagrams, histograms, heat maps, other visualization tools. Review on introduction to combinatorics and probability theory.

Unit 2 **(5 hrs)**

Some of the basic probability distributions: Binomial, Poisson, Exponential, and Normal. Central limit theorem.

Unit 3 **(4 hrs)**

Introduction to 'R': Introductory R language fundamentals and basic syntax, major R data structures, Using R to perform data analysis, creating visualizations using R.

Unit 4 **(6 hrs)**

Basic statistical inference and hypothesis testing: Estimation, basic tests such as t-test, z-test, F-test, χ^2 –test, Non parametric tests: Sign test, Wilcoxon signed rank test.

Unit 5 **(4 hrs)**

Regression methods: Simple linear regression and multiple regression.

Unit 6 **(4 hrs)**

Engineering applications of statistics (Branch Specific (any 2)): Discussion on reliability and quality control. Introduction to random processes, stochastic processes, Markov chains. Machine learning and data science.

Text Books

- Ronald E, Walpole, Sharon L. Myers, Keying Ye, Probability and Statistics for Engineers and Scientists (8th Edition), Pearson Prentice Hall, 2007.
- Tilman M. Davies, The book of R: A first course in Programming and Statistics (1st Edition), No Starch Press, USA, 2016.

Reference Books

- Ross S.M., Introduction to probability and statistics for Engineers and Scientists (8th Edition), Elsevier Academic press, 2014.
- S. P. Gupta, Statistical Methods, S. Chand & Sons, 37th revised edition, 2008.
- Kishor S. Trivedi, Probability and Statistics with Reliability, Queuing and Computer Science Applications (2nd Edition), Wiley Student edition, 2008.
- Stephens L.J., Schaum's outline of statistics for Engineers, Latest edition, 2019.
- The practice of Business Statistics by Manish Sharma and Amit Gupta, Khanna Publishing Company Private Limited, New Delhi, 2014.

References for R Software

- Norman Matloff, The Art of R Programming - A Tour of Statistical Software Design, (1st Edition), No Starch Press, USA, 2011.
- Sudha Purohit, Sharad Gore, Shailaja Deshmukh, Statistics using R (2nd Edition), Narosa Publications, 2019.
- Randall Pruim, Foundations and Applications of Statistics - An introduction using R (2nd Edition), American Mathematical Society, 2018.
- Hadley Wickham and Garrett Grolemund, R for Data Science: Import, Tidy, transform, Visualize and Model Data, (1st Edition), O'Reilly Publications, 2017.

ML 21002 Environmental Studies

(Adopted from the 'Ability Enhancement of Compulsory Courses: Environmental Studies' as prescribed by the Expert Committee of University Grants Commission as per directives of Hon'ble Supreme Court)

Teaching scheme
Lectures: 1 hr/week

Examination Scheme
Periodic Assignment & Test
Assignment: 2 hrs/week

Course Outcomes (COs):
At the end of the course, student will be able to:

- Comprehend sustainable development goals for present generation
- Appreciate environmental resources, functioning of an ecosystem, significance of biodiversity and environmental challenges
- Analyze the current status of environment with respect to precautionary mechanisms and control measures
- Appreciate the role of an engineer for better tomorrow

Unit 1 **(2 hrs)**

Multidisciplinary nature of environmental studies:
Definition, scope and importance, Need for public awareness.

Unit 2 **(8 hrs)**

Natural resources: Renewable and non-renewable resources:
Natural resources and associated problems.
Forest resources: Use and over-exploitation, deforestation, case studies. Timber extraction, mining, dams and their effects on forest and tribal people.Water resources : Use and over-utilization of surface and ground water,floods, drought, conflicts over water, dams-benefits and problems. Mineral resources : Use and exploitation, environmental effects of extracting and using mineral resources, case studies.Food resources : World food problems, changes caused by agriculture and overgrazing, effects of modern agriculture, fertilizer-pesticide problems, water logging, salinity, case studies.Energy resources : Growing energy needs, renewable and non renewable energy sources, use of alternate energy sources. Case studies.Land resources : Land as a resource, land degradation, man induced landslides, soil erosion and desertification.Role of an individual in conservation of natural resources.Equitable use of resources for sustainable lifestyles.

Unit 3 **(6 hrs)**

Ecosystems:
Concept of an ecosystem, Structure and function of an ecosystem, Producers, consumers and

decomposers, Energy flow in the ecosystem, Ecological succession, Food chains, food webs and ecological pyramids, Introduction, types, characteristic features, structure and function of the following ecosystem :-Forest ecosystem, Grassland ecosystem, Desert ecosystem, Aquatic ecosystems (ponds, streams, lakes, rivers, oceans, estuaries)

Unit 4 **(8 hrs)**

Biodiversity and its conservation

Introduction– Definition: genetic, species and ecosystem diversity, Bio geographical classification of India, Value of biodiversity : consumptive use, productive use, social, ethical, aesthetic and option values, Biodiversity at global, National and local levels, India as a mega-diversity nation, Hot-sports of biodiversity, Threats to biodiversity : habitat loss, poaching of wildlife, man-wildlife conflicts, Endangered and endemic species of India, Conservation of biodiversity : In-situ and Ex-situ conservation of biodiversity.

Unit 5 **(8 Hrs)**

Environmental pollution:

Definition, Cause, effects and control measures of :-Air pollution, Water pollution, Soil pollution, Marine pollution, Noise pollution, Thermal pollution, Nuclear hazards, Solid waste Management : Causes, effects and control measures of urban and industrial wastes, Role of an individual in prevention of pollution, Pollution case studies, Disaster management : floods, earthquake, cyclone and landslides.

Unit 6 **(7 hrs)**

Social issues and the environment:

From Unsustainable to Sustainable development, Urban problems related to energy, Water conservation, rain water harvesting, watershed management, Resettlement and rehabilitation of people; its problems and concerns. Case Studies, Environmental ethics : Issues and possible solutions, Climate change, global warming, acid rain, ozone layer depletion, nuclear accidents and holocaust. Case Studies, Wasteland reclamation, Consumerism and waste products. Environment Protection Act, Air (Prevention and Control of Pollution) Act, Water (Prevention and control of Pollution) Act, Wildlife Protection Act, Forest Conservation Act, Issues involved in enforcement of environmental legislation, Public awareness.

Unit 7 **(6 Hrs)**

Human population and the environment:

Population growth, variation among nations, Population explosion – Family Welfare Programme, Environment and human health, Human Rights, Value Education, HIV/AIDS, Women and Child Welfare, Role of Information Technology in Environment and human health, Case Studies.

Unit 8 **(5 Hrs)**

Field work:
Visit to a local area to document environmental assets river/ forest/grassland/hill/mountain Visit to a local polluted site-Urban/Rural/Industrial/Agricultural, Study of common plants, insects, birds, Study of simple ecosystems-pond, river, hill slopes, etc.

Reference Books:

- Agarwal, K.C. 2001 Environmental Biology, Nidi Publ. Ltd. Bikaner.
- Bharucha Erach, The Biodiversity of India, Mapin Publishing Pvt. Ltd., Ahmedabad – 380 013, India, Email:mapin@icenet.net (R)
- Brunner R.C., 1989, Hazardous Waste Incineration, McGraw Hill Inc. 480p
- Clark R.S., Marine Pollution, Clanderson Press Oxford (TB)
- Cunningham, W.P. Cooper, T.H. Gorhani, E & Hepworth, M.T. 2001,
- Environmental Encyclopedia, Jaico Publ. House, Mumabai, 1196p
- De A.K., Environmental Chemistry, Wiley Eastern Ltd.
- Down to Earth, Centre for Science and Environment (R)
- Gleick, H.P. 1993. Water in crisis, Pacific Institute for Studies in Dev., Environment & Security. Stockholm Env. Institute Oxford Univ. Press. 473p
- Hawkins R.E., Encyclopedia of Indian Natural History, Bombay Natural History Society, Bombay (R)

CT (IF) 21001 Data Analytics

Teaching Scheme:
Lectures: 1 Hr/week
Laboratory: 2 Hrs/week

Examination Scheme:
Continuous Lab/Project Assessment: 40 marks
Mid-Sem Exam: 30 Marks
End-Sem Exam: 30 Marks

Course Outcomes (COs):
At the end of the course student will be able to:
- Examine and compare various datasets and features.
- Analyze the business issues that analytics can address and resolve.
- Apply the basic concepts and algorithms of data analytics.
- Interpret, analyse, and validate data using popular data analytics tools.

Unit 1 **(2 hrs)**

Fundamentals of data analytics:

Descriptive, Predictive, and Prescriptive Analytics, Data Types, Analytics Types, Data Analytics Steps: Data Pre-Processing, Data Cleaning, Data Transformation, and Data Visualization.

Unit 2 **(2hrs)**

Data analytics tools:
Data Analytics using Python: Statistical Procedures, NumPy, Pandas, SciPy, Matplotlib.

Unit 3 **(2hrs)**

Data Pre-processing:
Understanding the Data, Dealing with Missing Values, Data Formatting, Data Normalization, Data Binning, Importing and Exporting Data in Python**,** Turning categorical variables into quantitative variables in Python, Accessing Databases with Python.

Unit 4 **(2hrs)**

Data visualization:
Graphic representation of data, Characteristics and charts for effective graphical displays, Chart types- Single var: Dot plot, Jitter plot, Error bar plot , Box-and-whisker plot, Histogram, Two variable: Bar chart, Scatter plot, Line plot, Log-log plot, More than two variables: Stacked plots, Parallel coordinate plot.

Unit 5 **(2hrs)**

Descriptive and inferential statistics:
Probability distributions, Hypothesis testing, ANOVA, Regression

Unit 6 **(4hrs)**

Machine learning concepts:
Classification and Clustering, Bayes' classifier, Decision Tree, Apriori algorithm, K-Means Algorithm, Logistics regression, Support Vector Machines, Introduction to recommendation system.

Text Books

- Anil Maheshwari, "Data Analytics made accessible," Amazon Digital Publication, 2014.
- James R. Evans, "Business Analytics: Methods, Models, and Decisions", Pearson 2012
- Song, Peter X. K, "Correlated Data Analysis: Modeling, Analytics, and Applications", Springer-Verlag New York 2007.

Reference Books:

- Glenn J. Myatt, Wayne P. Johnson, "Making Sense of Data I: A Practical Guide to Exploratory Data Analysis and Data Mining", Wiley 2009.
- Thomas H. Davenport, Jeanne G. Harris and Robert Morison, "Analytics at Work: Smarter Decisions, Better Results", Harvard Business Press, 2010
- Rachel Schutt, Cathy O'Neil, "Doing Data Science", O'REILLY, 2006.
- Shamanth Kumar Fred Morstatter Huan Liu "Twitter Data Analytics", Springer-Verlag, 2014.

Data Analytics Lab

List of Assignments:

1. Write a NumPy program to generate an array of 15 random numbers from a standard normal distribution.
2. Write a NumPy program to create a two-dimensional array with shape (8, 5) of random numbers. Select random numbers from a normal distribution (200, 7).
3. Write a Pandas program to add, subtract, multiple and divide two Pandas Series. Sample Series: [2, 4, 6, 8, 10], [1, 3, 5, 7, 9]
4. Write a Pandas program to convert a NumPy array to a Pandas series.
5. Write a Pandas program to create the mean and standard deviation of the data of a given Series.
6. Write a Pandas program to compute the minimum, 25th percentile, median, 75th, and maximum of a given series.
7. Write a Pandas program to get the day of month, day of year, week number and day of week from a given series of date strings.
8. Consider Iris Dataset, load the iris data into a data frame and perform following basic operations on it:
    a. Print the shape of the data, type of the data and first 10 rows and get the number of observations, missing values and nan values.
    b. Use Scikit-learn to print the keys, number of rows-columns, feature names and the description of the Iris data.
    c. Create a 2-D array with ones on the diagonal and zeros elsewhere. Now convert the NumPy array to a SciPy sparse matrix in CSR format
    d. Basic statistical details like percentile, mean, std etc. of iris data.
    e. Write a Python program to drop Id column from a given Data frame and print the modified part. Call iris.csv to create the Data frame.
    f. create a plot to get a general Statistics of Iris data
9. Consider the same Iris Dataset and perform visualization on the same:
    a. Write a Python program to create a Bar plot and pie plot to get the frequency of the three species of the Iris data.

b. Write a Python program to create a graph to see how the length and width of Sepal Length, Sepal Width, Petal Length, Petal Width are distributed.
c. Write a Python program to create a joinplot to describe individual distributions on the same plot between Sepal length and Sepal width.
   Note: joinplot - Draw a plot of two variables with bivariate and univariate graphs.
d. Write a Python program to draw a scatterplot, then add a joint density estimate to describe individual distributions on the same plot between Sepal length and Sepal width.
e. Write a Python program using seaborn to Create a kde (Kernel Density Estimate) plot of sepal_length versus sepal width for setosa species of flower.
f. Write a Python program to create a box plot (or box-and-whisker plot) which shows the distribution of quantitative data in a way that facilitates comparisons between variables or across levels of a categorical variable of iris dataset. Use seaborn.
g. Write a Python program to create a Principal component analysis (PCA) of iris dataset.

10. Write a Python program using Scikit-learn to split the iris dataset into 80% train data and 20% test data. Train or fit the data into the model and using the K Nearest Neighbor Algorithm and create a plot of k values vs accuracy.
11. Build a decision tree model that predicts the species of iris from the petal and sepal width and length. Perform model evaluation.
12. Implementing Support Vector Machine(SVM) classifier in Python using the iris features from iris dataset and train an SVM classifier and use the trained SVM model to predict the Iris species type.

Mini Project: Write an application demonstrating your skills in defining a data science problem, writing down the requirements carefully, designing a modular solution with clear separation of data pre-processing and transformation, visualization ,model building and model evaluation. The application can use any dataset from Kaggle, UCI etc or a task defined after discussion with the instructor.

This list is a guideline. The instructor is expected to improve it continuously.

Humanities and Social Sciences Open Courses-II
AS (HS) 21005 Industrial Psychology

Teaching scheme
Lectures: 2 hrs/week

Examination Scheme
Assignment/Test: 40 Marks
Final assessment: 60 Marks
Field Visit/ Expert Lecture Report: 20 Marks
Mini-project Report: 40 Marks

Course Outcomes (COs):
At the end of the course, student will be able to:

- Determine the psychological factors that influence individual differences at work and appraise the role of research.
- Explain the concepts of motivation and job satisfaction at work and Utilize the elements of organizational culture for enhancing group/team behavior.
- Evaluate the relevance & functioning of leadership & diversity in workforce and acknowledge the multicultural factors influencing workplace behavior.
- Illustrate the process of recruitment & selection and Experiment with the information required to sustain employability.
- Interpret the nuances of Human Factors in Engineering and Analyze itsrole in their disciplines.
- Measure the behavioral findings from self-lead projects and Propose corrective actions to improve quality of workplace behaviour.

Unit 1 **(6 hrs)**

Basics of industrial psychology (IP):
Difference between IP & business programs; major fields & employment in IP, brief history- scientific management, time and motion study, Hawthorne studies, World war I & II, Research in social sciences, Individual differences at work: personality, intelligence, emotional intelligence, creativity & innovation, perception & attitudes.

Unit 2 **(8 hrs)**

People at work:
Motivation & job satisfaction- employee predisposition, expectations, goals, incentives & equity; job characteristic theory (diagnostic model), Understanding groups & teams- group dynamics, factors affecting group performance; understanding work teams, types of teams, team development, issues with teamwork, Leadership (co-teaching 4 hrs)- leader characteristics, leader & situation, leader & follower; specific leadership skills, Introduction to organizational development (OD), diversity- multiculturalism- Hofstede's theory, diversity dynamics.

Unit 3 **(8 hrs)**

Human factors engineering (HFE):
Introduction & brief history of HFE; essentials of HFE, person-machine systems- basic human factors: sensory systems, perception, cognition, information processing approach, memory, decision making, workspace designs- general principles, designing work areas; machine displays & controls; physical work environment & anthropometry; managing workplace strain through ergonomics (self-study), current trends in HFE- use of artificial intelligence, cognitive engineering, sociotechnical systems, etc.

Unit 4 **(6 hrs)**

Managing people at work:
Job analysis- brief background, types & importance; job description, recruitment & selection- overview, process, evaluation, gearing for selection- interviews & job search skills, performance appraisal (co-teaching 2 hrs): steps in the evaluation process; appraisal interview.

Text Books

- Aamodt, M.G. (2013). Industrial Psychology. Cengage Learning: Delhi.
- Wickens, C. D.; Lee, J. D., Liu, Y. & Gordon Becker, S. E. (2015). An Introduction to Human Factors Engineering. 2nd Edition. Pearson Education: New Delhi.
- Landy, F. J. & Conte, J. M. (2010). Work in the 21st Century: An Introduction to Industrial and Organizational Psychology. 2nd Edition. Wiley India: New Delhi.

References

- Matthewman, L., Rose, A. & Hetherington, A. (2009). Work Psychology. Oxford University Press: India.
- Schultz, D. & Schultz, S. E. (2013). Psychology and Work Today: An Introduction to Industrial and Organizational Psychology. 7th Edition. Pearson Education: New Delhi.
- Schultz, D. & Schultz, S. E. (2002). Psychology and Work Today. Pearson Education: New Delhi.

AS (HS) 21006 Personnel Psychology

Teaching Scheme
Lectures: 2 hrs/week

Examination Scheme
Total: 100 Marks
Assignment: 60 Marks
End Semester: 40 Marks

Course Outcomes (COs):
At the end of the course, student will be able to:
- Acquire organizational concepts and will recognize their own personality attributes suitable for corporate world.
- Realize the importance of motivation and apply motivational principles to their lives
- Experience group dynamics and apply those principles in their lives
- Grasp and apply different techniques to maintain mental health.

Unit 1 **(6 hrs)**

Introduction- Understanding own personality and corporate world:
Basic concepts in organizational set up and its importance, know own personality attributes, preparing for corporate world, work ethics, and self- management

Unit 2 **(6 hrs)**

Motivation:
Motivational theories for self- motivation and motivating others at work place, Approaches to work

Unit 3 **(8 hrs)**

Group dynamics:
Group behavior and leadership, Effective group behavior, leadership and management principles, virtual teams and performance appraisal

Unit 4 **(6 hrs)**

Mental health at work place:
Occupational stress and conflict and strategies for its management, emotional intelligence, spiritual intelligence

****The course contents different psychometric tests, case studies and classroom activities.**

Text Books

- Khana S.S.- (2016) Organizational Behaviour(Text and Cases) Chand and company Pvt.Ltd.Delhi.
- Rae Andr'e :- (2008) organizational behavior. Dorling Kindersley (India) Pvt. Ltd.
- Wallace H.and Masters L.- (2008) Personality development..Cengage Learning India Pvt. Ltd.

Reference Books

- Robbins S, JudgeA, Vohra N:- (2013)Organizational behavior.(15thed) Pearson Education, Inc.
- Singh Kavita:- (2010) Organizational behavior-Text and cases. Dorling Kindersley

AS (HS) 21007 Engineering Economics

Teaching scheme
Lectures: 2 hrs/week

Examination Scheme
Assignment/Test: 40 Marks
End Semester: 60 Marks

Course Outcomes (COs):
At the end of the course, student will be able to:

- Demonstrate understanding of economic theories and policies.
- Identify economic problems and solve it by applying acquired knowledge, facts and techniques in the available framework.

- Categorize, classify and compare economic situations and draw inferences and conclusions.
- Adapt to changing economic atmosphere and propose alternative solutions to the problems.

Unit 1 **(6 hrs)**

Introduction to economics:
Definitions, basic concepts of economics: cost, efficiency and scarcity, opportunity cost, types of economics: micro economics, macroeconomics and managerial economics, difference between micro economics and macroeconomics, application of managerial economics.

Unit 2 **(8 hrs)**

Micro economics analysis:
Demand analysis, supply analysis, theories of utility and consumers choice, cost analysis, competition and market structures, application of micro economics theories.

Unit 3 **(8 hrs)**

Macro-economic analysis:
Aggregate demand and supply, economic growth and business cycles, inflation, fiscal policy, national income, theory of consumption, savings and investments, commercial and central banking, use of macro-economic theories.

Unit 4 **(8 hrs)**

International economics:
Balance of trade and balance of payments, barriers to trade, benefits of trade/comparative advantage, foreign currency markets/exchange rates, monetary, fiscal and exchange rate policies, economic development, application of exchange rate policies.

Reference Books

- Macroeconomics: N. Gregory Mankiw, 2018
- Managerial Economics: Economic Tools for Today's Decision Makers: by Paul Keat (Author), Philip Young (Author) 2013
- Principles Of Macro Economics: Misra and Puri.2009, Himalaya publishing house, New Delhi.
- Modern Microeconomics, A. koutsoyiannis , Macmillan , London
- Microeconomics Robert S. Pindyck and daniel L. rubinfeld:,pearson education Inc. New Delhi
- Micro economics: K. N. Verma

AS (HS) 21008 Finance for Engineers

Teaching scheme
Lectures: 2 hrs/week

Examination Scheme
Assignment: 40 Marks
End Semester: 60 Marks

Course Outcomes (COs):
At the end of the course, student will be able to:

- Comprehend basics of accounting, cost concepts, will be able to read Financial statements of companies
- Enable them to understand critical financial principles and to enable them to integrate & analyze financial information necessary for Business Decision Making.
- Establish relationship between Risk & Return, time value of money, sources of finance & working capital
- Appreciate the digital platform of future finance, crypto-currency, the terms associated with Financial Markets such as money market, capital market, SEBI & other Regulatory authorities

Unit 1 **(6 hrs)**

Introduction to accounting & finance:
Basic elements of financial accounting, cost concepts, preparation of profit & loss account & balance sheet & concept of budgetary control.

Unit 2 **(6 hrs)**

Read & interpret financial statements:
As per Schedule III of companies Act 2013, financial statement analysis, concept of cash flow statement.

Unit 3 **(8 hrs)**

Break-even analysis, Risk & Return relationship, time value of money, sources of finance & working capital.

Unit 4 **(4 hrs)**

Digital platform such as net banking, crypto-currency, algorithm based stock exchange trading, basics of money market, capital market, commodities market, IPO & regulatory authorities.

****Pedagogy:** Lectures and PPTs, Use of basic Excel tools for preparation of final accounts, Annual Reports of companies.

Reference Books

- Accounting for Managers – C Rama Gopal (2012), Accounting for Management, New Age International Publishers

- Financial Management – Theory and Practice - Prasanna Chandra [Mc Graw Hill] publication

Skill Based Course of the Domain
ME 21008 Design of Machine Components

Teaching Scheme
Practical: 2 hrs / week

Examination Scheme
Term work: 50 marks
Practical/Oral: 50 marks

Course Outcomes (COs):
At the end of the course students will be able to:

- Approach a design problem involving several mechanical components and take a decision when there is not a unique answer.
- Design and draw mechanical components.
- Use at least one drafting software.
- Use design data book.

Practical projects:
Term work shall consist of **"TWO"** design projects. Each project shall consist of two imperial size sheets – one involving assembly drawing with a parts list and overall dimensions and the other involving detailed drawings of individual components. Manufacturing tolerances, surface finish symbols and geometric tolerances should be specified so as to make it a working drawing. Use software for analysis and design proficiently.

A design report giving all necessary calculations of the design of components and assembly should be submitted in a separate file. Design project should be in the form of "Design of Machine components" comprising of various Machine elements covered in the syllabus. Design data book shall be used, wherever necessary, to select materials and standardized components. The drawings of one project shall be completed using design and drafting software.
The **ORAL** shall be based on Term Work.

ME 21001 Fluid Machinery & Fluid Power

Teaching scheme
Lectures: 3 hrs/week
Tutorial: 1 hr/week

Examination Scheme
Internal Test 1: 20 Marks
Internal Test 2: 20 Marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):
At the end of the course student will be able to:

- Design and evaluate performance of various Turbo Machines.
- Apply laws of fluid mechanics and governing equations for Turbo Machinery.
- Describe working of various components used for hydraulic & pneumatic systems.
- Design various hydraulic and pneumatic systems for industrial applications.

Unit 1 **(8 hrs)**

Momentum principle and its application:
Impulse- momentum principle, Calculation of force exerted on fixed plate, moving flat plates & curved vanes, Calculation force exerted on series of moving vanes, velocity diagrams & their analysis.

Unit 2 **(8 hrs)**

Turbines:
Classification, Various heads & efficiencies, Main components and constructional features of Pelton Wheel, Kaplan and Francis turbines, Velocity diagrams & analysis of Pelton, Francis turbines, Cavitation in water turbines, Governing mechanism, safety devices, Performance characteristics.

Unit 3 **(7 hrs)**

Centrifugal pumps:
Working principles, Construction, Types, Various heads, multistage pumps, Velocity triangles, Minimum starting speed, cavitation, Maximum permissible suction head (MPSH) and Net positive suction head (NPSH). Methods of priming, calculations of efficiencies, Discharge, Blade angles, Head, Power required Impeller dimensions etc. Specific speed and performance characteristics of pumps.

Unit 4 **(7 hrs)**

Fundamentals of fluid power:
Applications, advantages and dis-advantages of Hydraulic and Pneumatic systems. Various fluids used and their properties. Constructional details and Working of FRL unit. Drying of compressed air. Filters used in Hydraulic system.

Unit 5 **(7 hrs)**

Control valve & actuators :
Various types of Pressure, Direction & Flow control valves. Impulse valve, speed regulators, time delay valve, shuttle valve, twin pressure valve, solenoid operated valve. Constructional details and Working of various types of Actuators. Seals and Packing.

Unit 6 **(8 hrs)**

Hydraulic and pneumatic circuits:

Various symbols used. Basic Hydraulic and Pneumatic Circuits. Impulse operation, speed control, Actuation of pneumatic motor, sequencing of motion, use of roller operated valves, time delay circuit, Examples of Circuit design. Industrial Automation. Servo Mechanism.

Text Books

- Modi &Seth, Fluid Mechanics & Fluid Machinery, Standard Book House 2002.
- S.R. Majumdar, Pneumatic Systems Principles and Maintenance, Tata McGraw-Hill, N.Delhi, 2000.
- S.R. Majumdar, Oil Hydraulic Systems and Maintenance, Tata McGraw-Hill, N.Delhi, 2001.
- H.L. Stewart, Hydraulics and Pneumatics Power for Production, Industrial Press Inc. N.Y. USA, 2001.
- Andrew Parr, Butterworth and Heinemann, Hydraulics and Pneumatics, Oxford, UK, 1987.
- Espisito,Fluid Power with Application, Prentice Hall International,1998
- J.J.Pipenger ,Industrial Hydraulics, McGraw Hill, N.York, 1981.

Reference Books

- Industrial Hydraulics Manual-Vickers Sperry Rand Corporation, Technical Training Centre, N.York, 1988.
- Oil Hydraulics-P.Lal, International Literature, N.York, 1978.
- ISO-1219:1988 Fluid Systems and Components.
- Yeaple Franklin, Hydraulics and Pneumatics Power and Control, McGraw Hill Book. Co. N.York, 1966.
- R.K.Rajput,A Text book of Fluid Mechanics and Hydraulic Machines, S.Chand Co.Ltd.,2002

ME 21002 Metrology and Mechanical Measurements

Teaching scheme
Lectures: 3 hrs/week

Examination Scheme
Internal Test 1: 20 Marks
Internal Test 2: 20 Marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Apply knowledge of various tools and techniques used to determine geometry and dimensions of components in engineering applications.
- Design gauges to meet desired needs within realistic constraints.
- Perform experiments, as well as to analyze and interpret data.
- Apply the basic concepts of mechanical measurement for industrial applications.
- Describe methods of measurement for various quantities like force, torque, power, displacement, velocity/speed and acceleration.

Unit 1 **(8 hrs)**

Linear and angular measurements, **Interferometry, Measurement system analysis:**
A] Introduction: Meaning of Metrology, Precision, Accuracy, Methods and Errors in Measurement, Calibration.
B] Linear Measurement: Standards, Line Standards, End Standard, Wavelength Standard, Classification of Standards, Precision and Non -Precision Measuring instruments and their characteristics, Slip Gauges.
C] Interferometry: Introduction, Flatness testing by interferometry, NPL Flatness Interferometer. Study of Measuring Machines, Recent Trends in Engineering Metrology, use of interferometers for length, angle and surface roughness measurement.
D] Angle Measurement: Sine bars, Sine Centers, Uses of sine bars, angle gauges, Auto Collimator Angle Dekkor, Constant deviation prism.
E] Measurement System Analysis: Introduction, Influence of temperature, operator skills and the instrument errors etc. on the MSA.

Unit 2 **(6 hrs)**

Design of gauges, Interferometers and Comparators, Measuring machines:
A] Limits, Fits and Tolerances: Meaning of Limit, Fits and Tolerance, Cost – Tolerance relationship, concept of Interchangeability, Indian Standard System.
B] Design of limits gauges: Types, Uses, Taylor's Principle, Design of Limit Gauges, Three surface Generation.
C] Inspection of geometric parameters: Straightness, Flatness, Parallelism, Concentricity, Squareness, and Circularity.
D] Comparators: Uses, Types, Advantages and Disadvantages of various types of Comparators.
E] Measuring machines: Theory of Co-ordinate Metrology, Universal Measuring Machines, Co-ordinate Measuring Machines (CMM), different configurations of CMM, Principle, Error involved, calibration, Probing system, automated inspection system.

Unit 3 **(7 hrs)**

Surface finish measurement, Screw thread metrology, Gear metrology:
A] Surface finish measurement: Surface Texture, Meaning of RMS and CLA values, Roughness Measuring Instruments, Tactile and Non-tactile measuring instruments, difference between waviness and roughness, Grades of Roughness, Specifications, Assessment of surface roughness as per IS, Relationship between surface roughness and Manufacturing Processes.
B] Screw thread metrology: External Screw Thread Terminology, Floating Carriage Instruments, Pitch and flank Measurement of External Screw Thread, Application of Tool Maker's Microscope, Use of Profile Projector.
C] Gear metrology: Spur Gear Parameters, Gear Tooth Thickness Measurement: Gear Tooth Vernier Caliper, Constant Chord Method, Span Micrometer.

Unit 4 **(6 hrs)**

Introduction to mechanical measurements:
Importance of Measurements, Classification of measuring instruments, generalized measurement system, types of inputs for measurements. Concepts such as Linearity, Sensitivity, Static error, Precision, Reproducibility, Threshold, Resolution, Hysteresis, Drift, Span & Range etc. Errors in Measurements, Classification of errors in measurements, First order instruments and its response to step, ramp, sinusoidal and impulse inputs.

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Unit 5 **(6 hrs)**

Measurement methods and devices:
A] Displacement measurement: Transducers for displacement measurement, potentiometer, LVDT, Capacitance Types, Digital Transducers (optical encoder), Nozzle Flapper Transducer.
B] Velocity measurement: Tachometers, Tacho generators, Digital tachometers and Stroboscopic Methods.
C] Acceleration measurement: theory of accelerometer and vibrometers, practical accelerometers, strain gauge based and piezoelectric accelerometers.
D] Strain measurement: Theory of Strain Gauges, gauge factor, temperature Compensation, Bridge circuit, orientation of strain gauges for force and torque, Strain gauge based load cells and torque sensors.

Unit 6 **(6 hrs)**

Measurement – methods and devices:
A] Pressure measurement: Elastic pressure transducers viz. Bourdon tubes, diaphragm, bellows and piezoelectric pressure sensors, High Pressure Measurements, Bridge man gauge.
B] Temperature measurement: Thermocouple, Resistance thermometers, Thermistors, Pyrometers. Liquid in glass Thermometers, Bimetallic strip.
C] Vacuum measurement: Vacuum gauges viz. McLeod gauge, Ionization and Thermal Conductivity gauges.

Text Books

- R. K. Jain, A Text book of Engineering Metrology, Khanna Pblications Pvt. Ltd.18th Edition, 2002
- I.C.Gupta, A Text book of Engineering Metrology, Dhanpat Rai Publications Pvt. Ltd.6th Edition, 2004
- Anand Bewoor, Vinay Kulkarni.Metrology and measurement, Tata McGraw-Hill, first edition 2009.

- N.V. Raghavendra, L. Krishnamurthy, Engineering Metrology And Measurements,Oxford University Press,1st edition 2013
- R.K.Rajput A textbook of measurement and metrology ,S.K. Kataria & Sons,2013.
- R.K.Jain ,Mechanical and Industrial Measurements,Khanna Publishers,1995
- A.K.Sawhney,Mechanical measurement and control,Dhanpat Rai & Co. (P) Limited ,2017

Reference Books

- G.M.S. De Silva, Basic Metrology for ISO 9000 Certification Elsevier Publications, 3rd Edition 2002.
- Ernest Doebelin and Dhanesh Manik, Measurement Systems , McGraw-Hill, 6th Edition, 2017.

ME 21003 Heat Transfer

Teaching Scheme
Lectures: 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Anticipate and describe the consequence of heat transfer in thermal analyses of engineering systems.
- Formulate, evaluate and develop solution for one and two dimensional steady state heat conduction and unsteady state heat conduction problem.
- Describe fundamentals related to mass transfer and establish relationship between fluid flow and convection heat transfer.
- Apply empirical correlations for free and forced convection and phase change process to determine values for the convection heat transfer coefficient.
- Formulate and solve the heat exchanger rating and sizing problem.
- Evaluate radiation view factors using tables and obtain numerical solutions for radiation heat transfer problems.

Unit 1 **(6 hrs)**

One dimensional steady state heat conduction:

Introduction, derivation of Generalized heat conduction equation in Cartesian coordinates, Fourier, Laplace and Poission's equation. Generalized heat conduction equation in cylindrical and spherical co-ordinates. (no derivation). Heat conduction through a composite slab, cylinder and sphere, effect of variable thermal conductivity, critical radius of insulation, Economic insulation, and thermal contact resistance. Conduction with heat generation for plane wall, cylinder and sphere.

Unit 2 **(6 hrs)**

Extended surfaces and unsteady state heat conduction:
Types and Applications of Fins, Heat transfer through extended surfaces, derivation of temperature distribution equations and heat transfer through fins of constant cross-sectional area, Effectiveness and efficiency of a fin, Errors in the measurement of temperature in a thermo-well. System with negligible internal resistance, Biot and Fourier numbers. Lumped heat capacity method, use of Heisler charts.

Unit 3 **(5 hrs)**

Two dimensional steady state heat conduction:
Introduction to analytical method – two dimensional steady state heat conduction in rectangular plates, two dimensional steady state heat conduction in semi-infinite plates, graphical method – boundary conditions, conduction shape factors for common geometries.

Unit 4 **(9 hrs)**

Free and Forced convection:
Local and average convective coefficient, Hydrodynamic and thermal boundary layer, Laminar and turbulent flow over a flat plate and through a duct, Friction factor, Drag and drag co-efficient. Dimensional analysis in free and forced convection, physical significance of the dimensionless numbers related to free and forced convection, empirical correlations for free and forced convection for heat transfer in laminar and turbulent flow over a flat plate and through a duct.
Introduction to Condensation and Boiling, pool boiling, critical heat flux, burnout point, forced boiling. Film and drop wise condensation, determination of heat transfer coefficient.
Modes of Mass transfer, Concentrations, velocities and fluxes, Fick's law, general mass diffusion equation in stationery media, steady state diffusion through a plain membrane, steady state diffusion through a cylindrical shell, steady state diffusion through a spherical shell. Convective mass transfer.

Unit 5 **(6 hrs)**

Radiation:
Fundamental concepts, Black body radiation, Planck's distribution law, Wien's displacement law and the Stefan-Boltzmann law. Surface emission, radiative properties of a surface, The grey, black and real surface. Radiation shape factor, use of shape factor charts, Kirchhoff's law, Lambert's cosine law. Heat exchange between non-black bodies, heat exchange between two infinitely parallel planes and cylinders, Radiation shields, heat exchange by radiation, between two finite black/gray surfaces. Gas radiation (elementary treatment only). Solar radiation, irradiation, radiation potential, electrical network method of solving radiation problems.

Unit 6 **(6 hrs)**

Heat exchangers:
Heat exchangers classification, overall heat transfer coefficient, heat exchanger analysis, use of log mean temperature difference (LMTD) for parallel and counter flow heat exchangers, LMTD correction factor, fouling factor, The effectiveness-NTU method for parallel and counter flow heat exchangers. Design considerations of heat exchanger.

Text Books

- S.C.Arora, V. M. Domkundwar, A.V.Domkundwar, A course in Heat and Mass Transfer, Dhanpat Rai and Co. Pvt. Ltd, New Delhi
- S. P Sukhatme, A Text Book of Heat Transfer, University Press, 4th Edition, 2005
- R.K.Rajput, Heat and Mass Transfer, S. Chand and Co. Pvt. Ltd, New Delhi.

Reference Books

- Incropera and Dewitt: Fundamentals of Heat and Mass Transfer, John Wiley and Sons,NY.
- P.K.Nag, Heat and Mass Transfer, Tata McGraw-Hill, 2011
- Yunus A. Cengel, Heat Transfer: A Practical Approach, McGraw-Hill Higher Education, 2002
- J.P. Holman: Heat Transfer; McGraw-Hill, 1996
- C.P. Kothandaraman, S. Subramanyam, Heat and Mass Transfer Data Book, New Age International Publishers, Mumbai.

ME 21004 Design of Machine Components

Teaching Scheme
Lectures: 3 hrs / week
Tutorial: 1 hr/ week

Examination Scheme
100 Marks: Continuous Evaluation
Assignment/Quiz: 40 marks
End– Sem Exam: 60 marks

Course Outcomes (COs):
At the end of the course student will be able to:
- Evaluate the different types of stresses induced in a component due to different types of static loading conditions.
- Apply the principles of static loading to design various joints, keys, couplings, screws, and springs.
- Design shaft as per ASME code.
- Design welded joint for various loading conditions.

Unit 1 **(6 hrs)**

Fundamental aspects of design:

The meaning of design, engineering design, phases of design, design considerations, stress and strain considerations, factor of safety, standardization, preferred series, material selection – weighted point method.

Unit 2 **(6 hrs)**

Design against static load:
Commonly used engineering materials and their important mechanical properties – cast iron, mild steel, non-ferrous materials like Copper and Brass, stress-strain relationship, stresses due to bending and torsional load, design of cotter/knuckle, turn-buckle joints, riveted joints, eccentric loading and theories of failure.

Unit 3 **(6 hrs)**

Design of screws and fasteners:
Design of bolted and threaded joints, design of power screws, introduction to recirculating ball screw.

Unit 4 **(6 hrs)**

Design of shafts, keys and couplings:
Shafts subjected to bending and torsion, types of keys and their design, design of rigid and flexible couplings.

Unit 5 **(6 hrs)**

Design of springs:
Design of mechanical springs, helical torsion spring, design of multi leaf spring, nipping.

Unit 6 **(6 hrs)**

Design of welded joints:
Types of welded joints, eccentrically loaded joints, and welded joints subjected to bending moment.

Text Books
- Shigley J.E. and Mischke C.R. – "Mechanical Engineering Design" McGraw Hill Education (India) Ltd.
- Bhandari V.B. – "Design of Machine Elements" – McGraw Hill Education (India) Ltd.

Reference Books
- Spotts M.F. – "Design of Machine Elements" – Prentice Hall International.

- Black P.H. and O. Eugene Adams – "Machine Design" – McGraw Hill Book Co.Ltd.
- "Design Data" – P.S.G. College of Technology, Coimbatore.
- Hall A.S.; Holowenko A.R. and Laughlin H.G. – "Theory and Problems of Machine Design" – Schaum's outline series.

ME 21005 Fluid Machinery & Fluid Power Laboratory

Teaching Scheme
Practical: 2 hrs / week

Examination Scheme
Term work: 50 marks
Practical/Oral: 50 marks

Course Outcomes (COs):

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

- Evaluate performance of hydraulic turbines.
- Evaluate performance of centrifugal pump.
- Describe the construction, working and application of components used in hydraulic and pneumatic circuits.
- Design of various hydraulic and pneumatic circuits.

List of experiments:

The journal consisting of at least seven experiments among the following should be submitted. Two experiments out of first three and the sixth experiment is compulsory.

1. Study and trial on Pelton Turbine for performance testing.
2. Study and trial on Francis Turbine for performance testing.
3. Study and trial on Kaplan Turbine for performance testing.
4. Study & trial on centrifugal pump for performance testing.
5. Study & trial on gear pump for performance testing.
6. Design of Hydraulic Circuits by using Hydraulic Trainer Kit
7. Design of Pneumatic Circuits by using Pneumatic Trainer Kit
8. Demonstration of working of Hydraulic Press
9. Demonstration of cut sections of various Hydraulic Components

ME 21006 Metrology and Mechanical Measurements Laboratory

Teaching Scheme
Practical: 2 hrs / week

Examination Scheme
Term work: 50 marks
Oral: 50 marks

Course Outcomes (COs):

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

- Understand principle, construction and working of various measuring instruments,
- Select proper instruments for measurement
- Calculate least count of instrument, take reading using the instrument

- Interpret the observations & results.
- Collect and record data and analyse the data

Term Work / Experiments:

The term work shall consist of the conduction of any 12 experiments from the list given below.

1. Determination of Linear dimensions of a part using Precision and Non Precision measuring Instruments.
2. Precision angular measurement using a set-up of Sine Bar and Slip Gauges
3. Measurement of straightness, circularity, run out and total run out.
4. Measurement of screw thread parameters using Floating Carriage Micrometre.
5. Surface Finish measurement using suitable instrument.
6. Interferometry: Measurement of surface flatness using optical flat.
7. Study and Measurement of parameters using Profile Projector.
8. Exercise on Design of Limit Gauges using Taylor's Principles.
9. Study and Measurement of parameters using Tool Makers Microscope.
10. Demonstration of Digital Comparator and Pneumatic Comparator
11. Demonstration of CMM and Vision Measurement Machine
12. Measurement of temperature using RTD
13. Measurement of flow using flowmeter
14. Measurement of solar radiation flux density using pyranometer
15. Measurement of pressure using U tube manometer
16. Measurement of wind speed using anemometer

Assignments:

1. Exercise on Design of Limit Gauges using Taylor's Principles.
2. Develop a Matlab-Simulink model for First order instrument for various inputs.

ME 21007 Heat Transfer Laboratory

Teaching Scheme
Practical: 2 hrs / week

Examination Scheme
Term work: 50 marks
Practical/Oral: 50 marks

Course Outcomes (COs):

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

- Determine heat conduction properties of materials and observe heat transfer phenomenon and practically relate to concepts discussed in the heat & mass transfer course
- Account for the consequence of heat transfer in thermal analyses of engineering systems
- Analyze problems involving steady state heat conduction in simple geometries.
- Evaluate heat transfer coefficients for natural convection, for forced convection inside ducts, for forced convection over exterior surfaces.
- Calculate radiation heat transfer between black body surfaces and heat exchange between graybody surfaces.

Students have to perform **any eight** of the following experiments, make a report and submit as Term work for evaluation

List of Experiments:

1. Determination of thermal conductivity of a metal rod
2. Determination of thermal conductivity of insulating powder.
3. Determination of thermal conductivity of a given liquid.
4. Determination of thermal resistance of composite slab
5. Determination of Time required to Heat/Cool a body (Unsteady State Heat Conduction)
6. Determination of heat transfer coefficient in natural convection
7. Determination of heat transfer coefficient in forced convection for flow through cylinder
8. Determination of critical heat flux
9. Determination of emissivity of given surface
10. Determination of Stefan Boltzmann constant
11. Determination of effectiveness of heat exchanger (shell and tube type, cross flow type and plate type)

Minor in Product Design and Optimization
ME (MI) 21001 Product Design

Teaching scheme
Lectures: 3 hrs/week

Examination Scheme
Internal Test 1: 20 Marks
Internal Test 2: 20 Marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Practice various steps involved in the design of new product.
- Apply strategies involved in industrial design.
- Understand and implement the importance of economic factors in the product design.
- Apply principles of value engineering to new product development.
- Understand and exercise product development cycle, especially Booz Allen & Hamilton new product development cycle & ATAR model in financial analysis.

Unit 1 **(8 hrs)**

Introduction to product design:

Design by innovation, evolution, essential factors of product design, production consumption cycle (pcc), flow and value addition in pcc, morphology of design, primary phases of design, role of allowances, process capability and tolerances in design and assembly

Unit 2 **(6 hrs)**

Application of product design in industry:
Product design strategies in industry, pricing, quality, utility, luxuriousness, product analysis, simplification, designer and his role, Industrial design considerations, procedures, problems, types of models, role of aesthetics, functional design practices

Unit 3 **(6 hrs)**

Economic factors in product design:
Economic factors influencing design, product value, economic analysis, profit, competitiveness, break even analysis

Unit 4 **(6 hrs)**

Value engineering in product design:
Value, value analysis job plan, value analysis tests, cost reduction through value engineering, material and process selection in value engineering.

Unit 5 **(6 hrs)**

Product management:
Defining product by nature and demand, New product strategy, product classification, product development & management, product life cycle, Booz Allen & Hamilton new product development cycle, ATAR model applied to financial analysis in business.

Unit 6 **(6 hrs)**

Modern approaches to product design:
Concurrent engineering, rapid prototyping, reverse engineering, Quality function deployment.

Text Books

- Product Design and Manufacturing , K. Chitale, R. C. Gupta, PHI Publication, 2013
- Product Design, Creativity, Concepts and Usability, Prashant Kumar, , PHI Learning Pvt. Ltd. New Delhi, 2012

Reference Books

- Product Design and development, Karl T. Ulrich, Steven Eppinger, McGraw-Hill Education; 5th edition, 2011.
- New Product Development: Design & Analysis, Roland Engene Y., Inetoviez, John Wiley and Sons Inc., N.Y. 1990.

- Successful Product Design, Bill Hollins, Stuart Pugh, Butterworth, London, 1990.

Honor in Hybrid and Electric Vehicle
ME (HO) 21001 Automotive Engineering Systems

Teaching scheme
Lectures: 3 hrs/week

Examination Scheme
Research Assignment: 20 Marks
Internal Test: 20 Marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

At the end of the course students should be able to:

- Identify the need of transmission system, its function, and discuss different types of passenger car transmission systems.
- Calculate vehicle resistance, predict vehicle power requirement curve.
- Calculate transmission gear ratio's & predict vehicle performance.
- Categorize different vehicles bodies & layout's, its nomenclature, structural elements and synthesis it to meet vehicle crashworthiness requirements.
- Describe the different breaking & suspension systems in an automobile & demonstrate the vehicle safety.

Unit 1 **(4 hrs)**

Introduction:

History, Development of Vehicles & Drive Units, Stages in the Development of Automotive Transmissions, Development of Gear-Tooth Systems and other, Transmission Components, Basic Elements of Vehicle and Transmission Engineering, Need of Gearboxes, Functions of Vehicle Transmissions, and Fundamental Performance Features of Vehicle Transmissions, Trends in Transmission Design, Transmission Losses and Efficiency.

Unit 2 **(6 hrs)**

Basic design principles:

Arrangement of the Transmission in Passenger / Commercial / All-Wheel Drive Passenger Cars / Transverse and Longitudinal Dynamics with All-Wheel Drive, Transmission Formats & Designs, Basic Gearbox Concept. Passenger Car Transmissions: Manual Passenger Car Transmissions (MT); Automated Manual Passenger Car Transmissions (AMT); Dual Clutch Passenger Car Transmissions (DCT); Automatic Passenger Car Transmissions (AT); Passenger Car Hybrid Drives; Continuously Variable Passenger Car Transmissions (CVT). Final Drives: Axle Drives for Passenger Cars, Axle Drives for Commercial Vehicles, Differential Gears and Locking Differentials, Hub Drives for Commercial Vehicles; Transfer Gearboxes.

Unit 3 **(8 hrs)**

Passenger vehicle body:
The Automobile Body, Description of the Automobile Body Types (space frame, central frame, Body-on-frame, Monocoque), Body Nomenclature, Body Mass Benchmarking, Steel used in passenger vehicle. Vehicle layout, Different types of Car Body Style, Automotive Body Structural Elements, Overview of Classical Beam Behavior, Design of Automotive Beam Sections, Design for Crashworthiness: Standardized Safety Test Conditions and Requirements, Front Barrier, Side Impact, Note on Rear Impact.

Unit 4 **(12 hrs)**

Brakes, Suspension systems:
Type of brakes, Disc & Drum brake theory, constructional details, advantages, Brake actuating systems, Materials, and braking torque. Factors affecting brake performance, Parking & Exhaust brakes, power assisted brakes, Antilock Breaking System (ABS). Testing of brakes, thermal Considerations, Construction of suspension system, Solid Axles & Independent Suspension system, four-link & multi-link, Trailing Arm, Short Long Arm (SLA), MacPherson Strut suspension system, Anti-Squat, Anti-Pitch, and Anti-Dive suspension system, Roll Centre& stability Analysis

Text Books

- Harald Naunheimer, Bernd Bertsche, Joachim Ryborz, Wolfgang Novak "Automotive Transmission: Fundamentals, Selection, Design & Application" 2ndEdition, Springer-Verlag Berlin Heidelberg 1994, 2011
- Donald E. Malen "Fundamentals of Automobile Body Structure Design" SAE International Publication.
- K. Newton, W.Steeds and T.K.Garret, "The Motor Vehicle", 13thEdition, Butterworth Heinemann, India, 2004.
- P.M.Heldt, "Automotive Chassis", Chilton Co., New York, 1982.5.W.Steed, "Mechanics of Road Vehicles", Illiffe Books Ltd., London. 1992.
- Heinz Heisler, "Advanced Vehicle Technology", second edition, Butterworth –Heinemann, New York, 2002.

Reference Books

- William Crouse, "Automobile Engineering"
- Harban Singh Rayat, "The Automobile", S. Chand & Co. Ltd, New Delhi, 2000
- G.J.Giles, "Steering Suspension and Tyres", Illiffe Books Ltd., London, 1975
- Kirpal Singh, "Automobile Engineering", Standard publishers, Distributors, Delhi, 1999
- G.B.S.Narang, "Automobile Engineering", Khanna Publishers, Twelfth reprint New Delhi, 2005

- R.P.Sharma, "Automobile Engineering", Dhanpat Rai & Sons, New Delhi, 2000.
- Dr. N. K. Giri, "Automobile Mechanics", Seventh reprint, Khanna Publishers, Delhi, 2005
- Automotive Hand book/ Robert Bosch, SAE, 2003.8.2. K.K. Ramalingam, "Automobile Engineering ", Scitech Publications (India) PVT

Honour Course (Thermal Stream)
ME (HO) 21002 Fluid Dynamics

Teaching Scheme
Lectures: 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Understand and define the fluid flow problems along with range of governing parameters
- Use the governing equations for different flow conditions for exact and approximate solutions.
- Differentiate the different fluid flow patterns, flow regimes and its effects.
- Devise the fluid flow problems of industrial base.
- Design and develop experimental procedure for internal and external fluid flow conditions.

Unit 1 **(6hrs)**

Governing equations in Fluid Dynamics:

Reynolds Transport Theorem, Derivation of Continuity and Momentum equations using integral and differential approach, dimensionless form of governing equations, special forms of governing equations.

Unit 2 **(6hrs)**

Exact solutions of Navier-Stokes equations

Fully developed flows, parallel flow in straight channel – Couette flow with and without applied pressure gradients, Fully Developed Flow in a Round Pipe— Poiseuille Flow, unconfined Flow over the horizontal and inclined plate, Creeping flow approximation

Unit 3 **(6 hrs)**

Potential flow:

Irrotational flow approximations for continuity and momentum equations, Kelvin's theorem, Bernoulli Equation in Inviscid Regions of Flow, Two-Dimensional Irrotational Regions of Flow, Elementary Planar Irrotational Flows – uniform, source, sink, Irrotational Flows Formed by Superposition – doublet, flow past a half body, a Rankine Oval Body, a circular cylinder, lift and

drag Forces on Submerged Bodies – stationary and rotating cylinder. Drag Force acting on a rotating cylinder

Unit 4 **(7hrs)**

Boundary layer approximation:
Boundary layer equations, Laminar flat plate boundary layer exact solution, Turbulent flat plate boundary layer approximate solution, approximate solution methodology for boundary layer equations, Von-Karman integral Momentum equation for boundary layer, Pressure gradients in boundary layer flow, Separation of Boundary Layer, Control of Boundary Layer Separation

Unit 5 **(6hrs)**
Turbulent flow:
Characteristics of turbulent flow, laminar turbulent transition, time mean motion and fluctuations, Reynolds stresses, Prandtl's mixing length theory, derivation of governing equations for turbulent flow- Continuity, Reynolds Navier-Stokes equation, shear stress models, universal velocity distribution law and friction factor in duct flows for very large Reynolds number, Fully developed turbulent flow in a pipe for moderate Reynolds number.

Unit 6 **(8hrs)**

Experimental techniques:
Introduction to measurements related to fluid flow, Analysis of experimental data- types of errors, sources of error, uncertainty analysis, Measurement of temperature- thermoelectric thermometry, resistance thermometry, pyrometry, bimetallic and liquid crystal thermometer, Measurement of pressure-U-tube manometer, pressure transducers, Measurement of volume flow rate- orifice plate meter, flow nozzle, venturi meter, rotameter, velocity measurement based on thermal effect - Hot wire Anemometry, Laser Doppler Velocimetry, Particle Image Velocimetry

Text Books

- Muralidhar and Biswas, Advanced Engineering Fluid Mechanics, , Alpha Science International, 2005
- Hydraulics and Fluid Mechanics including Hydraulic Machines, Dr. P. N. Modi and Dr. S. M. Seth, Standard Book House, New Delhi

Reference Books

- Y.A.Cengel, J.M.Cimbala, Fluid Mechanics – Fundamentals and Applications,McGraw Hill, 2004
- Irwin Shames, Mechanics of Fluids, McGraw Hill, 2003

- Fox R.W., McDonald A.T, Introduction to Fluid Mechanics, John Wiley and Sons Inc,1985
- Pijush K. Kundu, Ira M Kohen and David R. Dawaling, Fluid Mechanics, Fifth Edition,2005

Honour Course (Design Stream)
ME (HO) 21003 Comprehensive Design

Teaching Scheme
Lectures: 3 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Demonstrate applicability of creativity, manufacturability, assembly, maintainability, emotions, reliability in the design of new products.
- Demonstrate the ability to identify needs of the customer and convert them in to technical specifications of a product.
- Generate different ideas after identifying the need and determining the specifications and constraints of a product for a particular purpose.
- Select appropriate material, manufacturing process, and shape by applying the principles of design for manufacturing.
- Apply various methods of rapid prototyping and reverse engineering to test and modify the designs.
- Design the components considering strength based reliability.

Unit 1 **(3 hrs)**

Product life cycle:

Development processes and organizations, product planning

Unit 2 **(10 hrs)**

Product design:

Need identification and problem definition, product specification, concept generation and selection, evaluation, creativity methods, concept testing

Unit 3 **(10 hrs)**

Design for manufacturing & assembly:

Selection of materials, Manufacturing processes & shapes for optimum design. Design for assembly,

Unit 4 **(6 hrs)**

Quality and robust design:
Design for reliability, strength based reliability, parallel and series systems, robust design, design for maintenance

Unit 5 **(3 hrs)**

Industrial design:
Design for emotion and experience, Introduction to retrofit design, Human behavior in design.

Unit 6 **(6 hrs)**

Modern methods of Design:
Various methods of rapid prototypingand reverse engineering, their applications, advantages and disadvantages.

Text Books

- Engineering Design, George E Dieter, McGraw Hill Company, 2000.
- Product Design, Creativity, Concepts and Usability, Prashant Kumar, Eastern economy edition, PHI New Delhi. 2012.

References

- Introduction to Engineering Design, Woodson T.T., McGraw Hill Book Company, 1966.
- Design Methods, John J.C., Wiley Inter Science, 1970.
- Simulation, modeling and analysis, Averil M. Law and W. David Kelton, McGraw Hill Book Company, 1991.
- Engineering Design – A Systematic Approach,Pahl, G. and W. Beitz, Springer. 2nd edition, 1996.
- Product Design and development, Karl T. Ulrich, Steven Eppinger,McGraw-Hill Education; 5th edition, 2011.

ML 21001 Constitution of India

Teaching scheme
Lectures: 1 hr/week

Examination Scheme
T1 and T2: 40 Marks
End-Sem. Exam: 60 marks

Course Outcomes (COs):
At the end of the course, student will be able to:

- Interpret the Preamble and know the basics of governance of our nation.

- Identify the different aspects covered under the different important Articles.
- Apprehend the basic law, its interpretation and the important amendments.
- Understand our Union and State Executive better.
- Recognize the basic that along with enjoying the rights one needs to fulfill one's duties.
- Summarize and Gain confidence on our Constitution by knowing it better.

Unit 1 **(5 hrs)**

Understanding the concept 'Rule of Law ', Meaning and history of Constitution, Introduction to The Constitution of India, understanding its objects, Preamble to the constitution of India.

Unit 2 **(4 hrs)**

Understanding the concept of Human Rights and Fundamental Rights, Fundamental rights under Part – III, exercise of the Rights, limitations and important cases, Prerogative Writs, Fundamental duties & their significance.

Unit 3 **(4 hrs)**

Relevance of Directive principles of State Policy, Legislative, Executive & Judiciary (Union and State), Constitutional Provisions for Scheduled Castes, Scheduled Tribes, & Backward classes, Constitutional Provisions for Women & Children.

Unit 4 **(2 hrs)**

Emergency Provisions, Electoral procedure in India, Amendment procedure and few important Constitutional Amendments.

Text Books:

- Introduction to the Constitution of India by Durga Das Basu (Students Edn.), Prentice – Hall EEE, 19th/20th Edn..
- Engineering Ethics by C. E. Haries, M. S. Pritchard and Michael J. Robins Thompson Asia,.

Reference Books:

- An Introduction to Constitution of India by M.V. Pylee, Vikas Publishing

Humanities and Social Sciences Open Courses-I
AS (HS) 21001 English Proficiency Language

Teaching scheme **Examination Scheme**

Lectures: 2 hrs/ week

T1 & T2: 60 Marks
End Semester: 40 Marks

Course Outcomes (COs):

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

- Understand concepts of English language and apply them practically.
- Reproduce meaningful and well-structured sentences for conversation or speech in English.
- Analyze, comprehend and write well and effectively produce enhanced formal communication in English.
- Display their Presentation skills and participate and produce healthy discussions both formally and informally among peers using English.
- Create impact by acquiring professional skills, confidently face interviews and be better employable and industry ready.

Unit 1 **(8 hrs)**

English for communication:

Basic understanding of language and its need for effective business communication for Engineers, formal and informal expressions, vocabulary building, business idioms.

Unit 2 **(6 hrs)**

Presentation skill development:

Oral presentations, basic mannerisms and grooming required for professionals, cross cultural communication, business etiquette.

Unit 3 **(8 hrs)**

Business writing:

Writing mechanics, note making, summarizing, letter &email writing, business reports, statement of purpose.

Unit 4 **(6 hrs)**

Employability enhancement:

Job readiness, interview skills and mock interviews.

Reference Books

- Business Communication by Shalini Verma (2nd Edition) (Vikas Publishing House)
- Communication for Business: A Practical Approach by Shirley Tailor (Longman)
- Communication Skills for Engineers by S. Mishra & C. Muralikrishna (Pearson)
- Communication Skills for Technical Students by T.M. Farhathullah (Orient Longman)
- Enhancing Employability at Soft Skills by Shalini Varma (Pearson)
- Written Communication in English by Saran Freeman (Orient Longman)

- Corporate Communication by Jaishri Jethwaney (Oxford University Press)
- Business Correspondence and Report Writing, R. C. Sharma & Krishna Mohan (McGraw Hill)
- Essential English Grammar (Intermediate & Advanced) Raymond Murphy (CUP)

AS (HS) 21002 German Language

Teaching scheme
Lectures: 2 hrs /week

Examination Scheme
Assignment: 40 Marks
End Semester: 60 Marks

Course Outcomes (COs):
At the end of the course, student will be able to:

- Acquire knowledge of facts about Germany and German culture (cultural sensitization).
- Adapt pronunciation of German letters and greetings.
- Identify and calculate numerical till 1000.
- Describe themselves and third person.
- Construct simple questions or sentences and interact with the teacher and classmates.
- Comprehend time and time related phrases, illustration of the same in conversations.
- Handle day to day situations like placing an order in the restaurant or interact with shopkeeper in the supermarket.

Unit 1 **(6 hrs)**

Guten Tag! (Good day):
Greetings, self introduction and partner introduction, numbers till 100, how to mention telephone number and email address, about countries, nationalities and languages.

Unit 2 **(6 hrs)**

Freunde, Kollegen und ich (Friends, colleagues and myself):
Hobbys, days of the week, months, seasons and professions, classroom objects and classroom communication.

Unit 3 **(6 hrs)**

Dining out:
Understanding German cusine, meal courses, names of the ingredients, conversation with the waiter and in the supermarket.

Unit 4 **(6 hrs)**

Uhrzeit (Timing):
Mention time, daily routine, making appointments

Unit 5 **(6 hrs)**

Grammatik (grammar):
Vocab, Verb conjugations, WH-question, verbs, pronounciation, personal pronouns, articles, Singular and Plural, negation.

Reference Books

- Dengler.S., Rusch. P., Schmitz.S., & Sieber.T. Netzwerk, Deutsch als Fremdsprache. 2015. Goyal Publishers & Distributors Pvt. Ltd. Delhi, India
- You tube video series "learn German", "easy German" etc.
- Funk.H., Kuhn.C., & Demme.S. Studio d A1. Deutsch als Fremdsprache. 2011. Goyal Publishers & Distributors Pvt. Ltd. Delhi, India.

AS (HS) 21003 Japanese Language

Teaching scheme
Lectures: 2 hrs/week

Examination Scheme
Assignment: 40 Marks
End Semester: 60 Marks

Course Outcomes (COs):
At the end of the course, student will be able to:

- Acquire knowledge of facts about Japan and Japanese culture,
- Familiarize with pronunciation of Japanese letters and daily greetings, accent, intonation and Japanese writing system Hiragana, Katakana and Kanji
- Identify numbers, colors, years, months and days, time expressions, directions to read the city map.
- Describe themselves and third person and family members
- Construct simple questions or sentences and interact with the teacher and classmates.
- Apply engineering terminology and Japanese work culture such as Monozukuri, 5S, Kaizen, 3M, 5W1H etc.

Unit 1 **(6 hrs)**

Introduction to Japanese language (Nihongo):
Recognize Japanese Characters Hiragana. Can read /write Hiragana script, Use basic classroom expressions, Exchange greetings Can thank someone or apologize someone, Recognize Japanese Characters Katakana Can read /write Katakana script, Can ask someone to say something again if you don't really understand.

About Me & food:
Give simple self introduction Can ask and answer where you live and your age, Can write your name, nationality, date of birth and occupation in Japanese, Recognize the parts of a business card, Talk someone briefly about your family using a family photo and answer simple questions such as who is that? Number of family members.

Talk about your favorite foods you like and dislike. Talk about your breakfast, Can respond when offered a drink. For example saying what you want to drink, Can look at menu in a fast

food restaurant and understand what is available, Can look at different restaurants' signboards and understand what each place is.

Unit 2 **(6 hrs)**

Home and Daily life:
Say what kind of house you live in. Say what you have in your home, Write an e mail inviting someone to your home. Visit/ Welcome a friend, Ask /say where to put things in the room. Can read the buttons on an electric appliance, Can listen to a simple explanation when being shown around a room and understand the layout, Recognize the name and address on signs.
Talk about your daily routine. Say the time you do something, Talk about your schedule at work for the week, Can listen to short and simple instructions at work and understand what to do, Can read a simple, handwritten note at work and understand the instructions, Can ask someone to lend you something at work, Can look at a list of equipment and confirm if you have all the items.

Unit 3 **(7 hrs)**

Holidays and days off 1 and Towns:
Can give a simple answer when asked about your hobbies and favorite things to do, Talk about what you do on your days off, Can read an event poster and find the important information such as the date, time and place, Can ask and answer questions about whether you are going to an event etc., Can say when you are available, when you are inviting someone to something or being invited.
Recognize station and Taxi signs, How to get to particular destination using a map, Can say how you go to work and how long it takes, Describe places in town and location, Can look at common signs in a station and understand what they mean.

Unit 4 **(6 hrs)**

Shopping and Holidays and days off 2:
Talk about what you want to buy, Can ask staff in a shopping center etc. Where to go for a certain item and understand the answer, Can look at discount signs and read the prices. Make a brief comment on things in a shop.
Can read a short blog / simple e mail, Can talk in simple terms about impressions of the holiday/trip, Can write a simple post for social media etc. About what you did in holiday.

References:

- Marugoto A1 Katsudo Starter Coursebook for Communicative Language Activities.
- Marugoto A1 Rikai Starter Coursebook for Communicative Language Competences
- The Japan Foundation
- Minna no Nihongo Main Textbook Elementary Lesson 1-12
- Minna no Nihongo Translation & grammatical Notes in English Elementary Lesson 1-12,3A Corporation Goyal Publishers

AS (HS) 21004 Spanish Language

Teaching scheme
Lectures: 2 hrs/week

Examination Scheme
Assignment: 40 Marks
End Semester: 60 Marks

Course Outcomes (COs):
At the end of the course, student will be able to:

- Acquire knowledge of facts about Spain and Latin Americaand Spanish culture, pronunciation of Spanish letters and greetings.
- Identify and calculate numerical till 1000.
- Describe themselves and third person.
- Construct simple questions or sentences and interact with the teacher and classmates.
- Comprehend time and time related phrases, illustration of the same in conversations, handle day to day situations like placing an order in the restaurant or interact with shopkeeper in the supermarket.

Unit 1 **(6 hrs)**

¡Hola! (Hello)
Greetings, self introduction and partner introduction, numbers till 100, how to mention telephone number and email address, about countries, nationalities and languages. Hobbys, days of the week, months, seasons and professions, classroom objects and classroom communication.

Unit 2 **(6 hrs)**

La comida (Food):
Understanding Spanish cusine, meal courses, names of the ingredients, converstaion with the waiter and in the supermarket.

Unit 3 **(6 hrs)**

La ropa (clothing):
Clothing, accessory (as per weather), season+ weather, vocabulary, Demonstrative pronouns, how to ask about price, numbers till 1000.

Unit 4 **(6 hrs)**

La hora (Timing):
Mention time, daily routine, making appointments

Unit 5 **(6 hrs)**

La gramática (grammar)
Vocab, Verb conjugations, WH-question, verbs, pronounciation, personal pronouns, articles, Singular und Plural, negation.

Reference Books

- Aula internacional 1Jaime Corpas, Eva García, Agustín Garmendia, Neus Sans Baulenas (contributor), published by Goyal Publisher's and Distributors Pvt. Ltd.

HS 21001 Entrepreneurship Principles and Process

Teaching scheme
Lectures: 1 hr/week

Examination Scheme
Field Work /Assignment: 40 Marks
End Sem. Exam: 60 marks

Course Outcomes (COs):
At the end of the course, student will be able to

- Discover, develop, and assess different types of Entrepreneurial ventures and opportunities.
- Learn about opportunity and risk analysis
- Use the strategies for valuing your own company, and how venture capitalist and angel investors use valuations in negotiating milestones, influence and control
- Pick correct marketing mix and how to position the company in the market by using analytical tools
- Learn how to sale themselves and the product/service and to handle objections
- Know how organizations operates, their process matrices, start new ventures, write winning business plans

Unit 1 **[3 Hrs]**

Market research, types of companies and organizations
Introduction to Entrepreneurship, Profile of the Entrepreneur, Market Gap /Opportunity Analysis, Market Research Methods, Defining the Focal Market: Market Segmentation, Industry analyzing– Research /Competitive Analysis. Company/ Organization Types, Legal Aspects, Taxation, Government Liaison, Building the Team, Mergers and Acquisitions

Unit 2 **[4 Hrs]**

Business finance, marketing & digital marketing
Shares and Stakes, Valuation, Finance Creation (Investors/Financers), Revenue Plans and Projections, Financial Ratios, Business Lifecycle, Break Even. Marketing Basics, Marketing Strategy and Brand Positioning, Plans and Execution Techniques, Marketing Analytics, Online Marketing

Unit 3 **[3 Hrs]**

Sales & Operations management
Understanding Sales, Pitching Techniques, Sales strategies, Inside Sales v/s Outside Sales, RFP Operational Basics, Process Analysis, Productivity, Quality

Unit 4 **[2 Hrs]**

Start-ups
Start-up Basics, Terms, Start-up Financing, Start-up Incubation, Start-up Incubation, Getting Listed

Text Books

- The Startup Playbook:Secrets of the Fastest-Growing Start ups From Their Founding Entrepreneurs by David Kidder
- True North by Bill George and Peter Sims
- Cardullo,M.W.P.E.(1999).Technological entrepreneurism: Enterprise formation, financing, and growyh. England:Research Studies Press Ltd.

References

- Kanungo,R.N.(1998).Entrepreneurship and innovation: Models for development (Ed.,Vol.2). New Delhi: Sage.
- Van Nostrand.Verma, J.C.,& Singh,G.(2002).Small business and industry: A hand book for entrepreneurs. New Delhi: Response-Sage.
- Richard A Brealy & Steward C Myres. Principles of Corporate Finance, McGraw Hills, 7th Edn, 2004
- Prasanna Chandra, Financial Management:Theory and Practice,Tata McGraw Hills, 6th Edn, 2004 IM Pandey,Financial Management,Vikas Publishing

ME 21016 Mini Project

Teaching Scheme
Practical: 4 hrs / week

Examination Scheme
Term work: 50 marks
Oral: 50 marks

Course Outcomes (COs):
At the end of the course, students will demonstrate the ability to:

- Conceive a problem statement either from rigorous literature survey or from the requirements raised from need analysis.
- Design, implement and test the prototype/algorithm in order to solve the conceived problem.
- Write comprehensive report on mini project work.

Guidelines:

1. The mini-project is a team activity having 3-4 students in a team. Mini project should include mainly Mechanical Engineering contains but can be multi-disciplinary too.
2. The mini project may be a complete hardware or a combination of hardware and software. The software part in mini project should be less than 50% of the total work.
3. Mini Project should cater to a small system required in laboratory or real life.
4. It should encompass components, devices etc. with which functional familiarity is introduced.
5. After interactions with course coordinator and based on comprehensive literature survey/ need analysis, the student shall identify the title and define the aim and objectives of mini-project.
6. Student is expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and submit the proposal within first week of the semester.
7. The student is expected to exert on design, development and testing of the proposed work as per the schedule.
8. Completed mini project and documentation in the form of mini project report is to be submitted at the end of semester.

ME 21009 Computational Methods and Programming

Teaching Scheme
Lectures: 2 hrs / week

Examination Scheme
Research assignment: 20 marks
Practical exam: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):
At the end of the course students should be able to:

- Use numerical methods in modern scientific computing.
- Determine numerical solutions of nonlinear equations in a single variable.
- Use numerical interpolation.
- Estimate solution to problems using numerical integration and differentiation.
- Obtain numerical solution to engineering problems using programming.

Unit 1 **(6 hrs)**

Numerical methods I:
Introduction to numerical methods: Difference between analytical & numerical approach
Error Approximations: Types of Errors: Absolute, Relative, Algorithmic, Truncation, Round off Error, Error Propagation, Concept of convergence-relevance to numerical methods
Roots of equations: Bracketing and Open Methods
Simultaneous Equations: Gauss-Elimination, with partial pivoting, Gauss-Seidal, Gauss- Jordan, Gauss-Jacobi, Thomas algorithm for Tri-diagonal Matrix

Unit 2 **(6 hrs)**

Numerical methods II:

Numerical Integration: Trapezoidal rule, Simpson's 1/3rd Rule, Simpson's 3/8th Rule, Gauss Quadrature 2 point and 3 point method. Double Integration using Trapezoidal rule, Simpson's 1/3rd Rule

Ordinary Differential Equations [ODE]: Taylor series method, Euler Method, Runge-Kutta fourth order, Simultaneous equations using RungeKutta2nd order method

Partial Differential Equations [PDE]: Finite Difference methods Introduction to finite difference method, Simple Laplace method, PDEs- Parabolic explicit solution, Elliptic-explicit solution

Unit 3 **(6 hrs)**

Curve fitting and Regression analysis :

Interpolation: Approximation by Forward, Backward, Central and Divided Difference Formulae, Interpolation by Newton's Formulae, Lagrange's, Spline Interpolation, Hermite and Stirling Formulae

Curve fitting: Least square technique- Straight line, Power equation, Exponential equation and Quadratic equation

Regression using Machine Learning algorithms: Linear Regression, Logistic Regression, Polynomial Regression, Support Vector Regression, Regression trees: Decision tree, random forest, Ridge Regression, Lasso Regression, Clustering/ K-Means, K-Nearest Neighbor (KNN), Neural Networks

Text Books

- Steven C. Chapra, Raymond P. Canale, Numerical Methods for Engineers, 4th edition, Tata McGraw Hill Co-Ltd
- Steven C. Chapra, Applied Numerical Methods with MATLAB for Engineers and Scientist, 2nd edition, Tata McGraw Hill Co-Ltd
- S. S. Sastry, Introductory Methods of Numerical Analysis, Prentice Hall of India Delhi
- Rajaraman, "Computer Oriented Numerical Methods", Prentice Hall of India Delhi
- T Veerarajan, T Rama Chandran, "Theory and Problems in Numerical Method" Tata McGraw Hill Co-Ltd

Reference Books

- William H. Press, Saul A. Tenkolsky, William T, Vellering, Brain P. Flannery "Numerical Recipes in C", Cambridge University Press
- Alex Smola and S.V.N. Vishwanathan, Introduction to Machine Learning, Cambridge University Press
- Rudolph Russell, Machine Learning: Step-by-Step Guide to Implement Machine Learning Algorithms with Python, an open source book.

- Aurélien Géron, Hands-On Machine Learning with Scikit-Learn and TensorFlow Concepts, Tools, and Techniques to Build Intelligent Systems, O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

ME 21010 Theory and Design of Mechanical Systems

Teaching Scheme
Lectures: 3 hrs / week
Tutorial: 1 hr/week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Apply fundamental principles of fatigue and stress concentration while designing various components.
- Design spur, helical, bevel and worm gears.
- Select of sliding and rolling contact bearings.
- Explain and select different types of transmission drives.
- Identify different type of vibrations and calculate natural frequency of various systems.
- Apply balancing concept to various types of rotating and reciprocating machine elements.

Unit 1 **(6 hrs)**

Design against fluctuating load:

Stress concentration, fatigue failure, endurance limit, notch sensitivity, Goodman and Soderberg diagrams, and modified Goodman diagram.

Unit 2 **(4 hrs)**

Bearings:

Working principle of hydrodynamic, hydrostatic bearing and rolling contact bearing. Classification of bearings. Selection of bearings from manufacturer's catalogue. Comparison of sliding contact and rolling contact bearings.

Unit 3 **(10 hrs)**

Design of gears:

Terminology, force analysis, gear tooth failures of spur gear, helical gear, bevel gear and worm gear. Design of all above mentioned types of gears. Methods of lubrication.

Unit 4 **(6 hrs)**

Friction drives:

Belts, Clutches and Brakes: types, power and torque transmission, and absorption derivations.

Unit 5 **(6 hrs)**

Balancing:
Static and dynamic balance, balancing of revolving several masses on several planes, balancing of reciprocating masses in single and multi cylinder engines, balancing machines.

Unit 6 **(8 hrs)**

Mechanical vibrations:
Fundamentals, undamped and damped free vibrations of single degree freedom system, forced vibration of single degree of freedom system, critical speed of shafts.

Text Books

- Bhandari V.B. – "Design of Machine Elements" – McGraw Hill Education (India) Ltd.
- Shigley J.E. and Mischke C.R. – "Mechanical Engineering Design" McGraw Hill Publ. Co.Ltd.
- Ballaney, P.L., "Theory if Machines and Mechanisms", 2005, ISBN 9788174091222
- Hannah and Stephens, "Mechanics of Machines: Advanced Theory and Examples", 1970, ISBN 0713132329 Edward Arnold London

Reference Books

- Spotts M.F. – "Design of Machine Elements" – Prentice HallInternational.
- Black P.H. and O. Eugene Adams – "Machine Design" – McGraw Hill BookCo.Ltd.
- "Design Data" – P.S.G. College of Technology,Coimbatore.
- Hall A.S.; Holowenko A.R. and Laughlin H.G. – "Theory and Problems of Machine Design" – Schaum"s outlineseries.
- Ulicker Jr. J.J., Penock G.R. & Shigley J.E. "Theory of Machines and Mechanisms" Tata McGraw Hills
- Ghosh Amitabha & Mallik Asok Kumar, "Theory of Mechanisms and Machines" east-West Press Pvt. Ltd. New Delhi

ME 21011 Steam and Gas Turbine

Teaching Scheme
Lectures: 3 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):
This course is designed to expose the students to the practical applications of thermodynamics at the end of this course students will be able to:

- Acquire specific knowledge of components of the thermal power plant such as boiler, nozzles, turbines, condensers, gas turbine, and jet engine.
- Evaluate the thermal performance of steam nozzles, steam turbine, steam condensers, cooling tower, gas turbine, and suggest methods for improvement of performance.
- Apply turbo machinery design principles to the gas turbine engine.
- Analyze thermodynamic cycles of gas turbine power plant and jet propulsion systems

Unit 1 **(6 hrs)**

Steam generator:
Introduction to layout of thermal power plant, principle of steam generation, fuel for steam generators, necessity of water treatment, classification of steam generators, fire tube and water tube boilers, high pressure and supercritical boilers, boiler mountings and accessories. Performance of steam generators: Evaporation capacity, equivalent evaporation, boiler efficiency.

Unit 2 **(6 hrs)**

Steam nozzles:
Adiabatic expansion in nozzles, maximum discharge, critical pressure ratio, choking, effects of friction, nozzle efficiency, calculation of throat and exit areas, supersaturated flow, Wilson Line.

Unit 3 **(8 hrs)**

Steam turbines:
Working principle of steam turbines, classification of steam turbines, comparison of impulse and reaction turbines, compounding of steam turbines, flow of steam through turbine blades, Reheat factor, Velocity diagrams, Performance analysis graphical and analytical methods, steam turbine efficiencies, governing of turbines and Losses in turbines.

Unit 4 **(6 hrs)**

Steam condensers and cooling towers:
Types of condensers, classification of condensers, quality and quantity of cooling water required, calculations for surface condenser, Dalton's law of partial pressure, sources of air leakages and air removal, air ejectors. Cooling towers: wet cooling towers, dry cooling towers, cooling ponds.

Unit 5 **(8 hrs)**

Gas turbines:

Classification, open and closed cycle, gas turbine fuels, actual Brayton cycle, optimum pressure ratio for maximum thermal efficiency, work ratio, air rate, effect of operating variables on the thermal efficiency and work ratio, and air rate, simple open cycle turbine with regeneration, reheating and Intercooling, Combined steam and gas turbine plant, requirements of combustion chamber, types of combustion chambers.

Unit 6 **(6 hrs)**

Jet Propulsion:
Fundamental of propulsion technology, Turbojet Engine, thrust, thrust power, propulsive efficiency, thermal efficiency, Turboprop, Ramjet, scramjet and Pulsejet engines.

Text Books

- Yunus Çengel and Michael, Boles "Thermodynamics: An Engineering Approach", 3rd Edition, Tata McGraw Hill.
- T. D. Eastop and A. Mc Conkey, "Applied Thermodynamics", Addison Wesley Longman
- R. Yadav, "Steam & Gas Turbines & Power Plant Engineering", Central Publishing House, Allahabad, 2004
- R. C. Patel and C. J. Karamchandani, Elements of Heat Engines vol. I, II, and III, 18th Edition 1997, Acarya Publications Vadodara

Reference Books

- Thermodynamics, 4th Edition, J.P. Holman, McGraw-Hill.Engineering Thermodynamics, 2nd Edition, Jones J.B. and Hawkins G.A., John Wyley and Sons.
- Fundamentals of Engineering Thermodynamics, Moran M.S. and Shapiro H.N., John Wyley and Sons, 1988. Thermodynamics, 5th Edition, K. Wark, McGraw-Hill
- A Course in Power Plant Engineering, Arora & V.M. Domkundwar, Dhanpat Rai & Sons
- P.K. Nag, "Power Plant Engineering", 2nd edition Tata McGraw Hill,
- Power Plant Engineering, M. M. EI- Wakil, McGraw Hill International

List of Open Source Software/learning website:
- http://nptel.ac.in/courses/112104117/18
- http://nptel.ac.in/courses/112104117/4
- http://nptel.ac.in/courses/112104117/17

ME 21012 Fuels and Combustion

Teaching Scheme
Lectures: 3 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks

End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Analyze the properties of fuels
- Compare the suitability of fuels utilization poit of view.
- Evaluate the performance of an engine.
- Demonstrate stages of combustion in SI and CI engine
- Analyze the emission and performance of an engine.

Unit 1 **(4 hrs)**

Characterization:

Fuels - Types and Characteristics of Fuels, Fuels Analysis, Proximate and Ultimate Analysis, Moisture Determination, Calorific Value, Gross & Net Calorific Values, Calorimetry, DuLong's Formula for CV Estimation, Flue gas Analysis.

Unit 2 **(6 hrs)**

Solid fuels:

Coal Family, Properties, Calorific Value, DMMF, DAF and Bone Dry Basis, Ranking, Storage, Washability, Coking & Caking Coals, Renewable Solid Fuels, Biomass, Wood Waste, Agro Fuels, Manufactured Solid Fuels.

Liquid fuels:

Sources, Petroleum Fractions, Classification, Refining, Properties of Liquid Fuels, Calorific Value, Specific Gravity, Flash & Fire Point, Octane Number, Cetane Number etc, Alcohols, Liquefaction of Solid Fuels

Unit 3 **(4 hrs)**

Gaseous fuels:

Classification, Composition & Properties, Estimation of Calorific Value, Gas Calorimeter, Rich & Lean Gas, Wobbe Index, Natural Gas, LPG, LNG, CNG, Methane, Producer Gas, Water Gas, Town Gas, Coal Gasification, Gasification Efficiency, Biogas.

Unit 4 **(2 hrs)**

Combustion:

Combustion equations, stoichiometric air fuel ratio, enthalpy of formation, adiabatic flame temperature.

Unit 5 **(10 hrs)**

SI and CI Engine:
Otto cycle, fuel supply system, stages of combustion in SI engines, abnormal combustion and knocking in SI engines, factors affecting knocking, effects of knocking, control of knocking, combustion chambers for SI engines
Diesel cycle, fuel supply system, stages of combustion in C.I. Engines, delay period, factors influencing delay period, diesel knock, control of diesel knock, types of combustion chamber.

Unit 6 **(10 hrs)**

Performance and Emission:
Engine Performance and parameters, determination of IP, BP, FP, IMEP, BMEP, various efficiencies, energy balance, performance of CI and SI engine. Exhaust after treatment, catalytic converters, exhaust gas recirculation, emission control in engines, sources of SI and CI engine emission, Euro and Bharat stage norms, Emission control methods in SI and CI engine

Text Books

- Ganesan. V, "Internal Combustion Engines", Tata McGraw Hill
- Mathur & Sharma, "A Course in Internal Combustion Engines", R. P. Dhanapat Rai Publications.
- Samir Sarkar, Fuels & Combustion, 2nd Edition, Orient Longman, 1990

Reference Books

- Edward E. Obert, "Internal Combustion Engines and Air Pollution", Internal Educational Pub, 1973
- Crouse W.H., "Automotive Mechanics", McGraw Hill
- Heywood J., "I.C. Engines Fundamentals", McGraw Hill publications
- Sharma SP, Mohan Chander, Fuels & Combustion, Tata McGraw Hill, 1984

ME 21013 Computational Methods and Programming Laboratory

Teaching scheme
Practicals: 2 hrs/week

Examination Scheme
Term work: 50 Marks
Practical Exam: 50 Marks

Course Outcomes (COs):
At the end of the course students should be able to:
- Use numerical methods in modern scientific computing.
- Determine numerical solutions of nonlinear equations in a single variable.
- Use numerical interpolation.
- Estimate solution to problems using numerical integration and differentiation.

- Obtain numerical solution to engineering problems using programming.

Experiments:

1. Design of an algorithmfor findingroots of equation (Iteration & accuracy criteria based)
    a. Bisection Method
    b. Regula Falsi Method
    c. Newton Raphson Method
    d. Successive approximation Method
2. Design of an algorithm for finding solution of simultaneous equations
    a. Gauss-Elimination, with partial pivoting,
    b. Gauss-Seidal,
    c. Gauss- Jordan,
    d. Gauss-Jacobi,
    e. Thomas algorithm for Tri-diagonal Matrix
3. Design of an algorithm for finding numerical integration
    a. Trapezoidal rule
    b. Simpson's $1/3^{rd}$ Rule
    c. Simpson's $3/8^{th}$ Rule
    d. Gauss Quadrature 2 point and 3 point method
    e. Double Integration using Trapezoidal rule, Simpson's $1/3^{rd}$ Rule
4. Design of an algorithm for solving ODE
    a. Euler Method
    b. Runge-Kutta Methods-fourth order
    c. Simultaneous equations using Runge-Kutta 2nd order
    d. Simple pendulum equation or Spring mass damper equation
5. Design of an algorithm for solving PDE
    a. Finite Difference methods
    b. Simple Laplace method
    c. Parabolic explicit solution
    d. Elliptic-explicit solution
6. Design of an algorithm for fitting a curve using Least square technique
    a. Straight line
    b. Power equation
    c. Exponential equation
    d. Quadratic equation
7. Design of an algorithm for interpolation
    a. Lagrange's Interpolation
    b. Newton's Forward interpolation
8. Design of an algorithm for predictive modelling using Machine Learning algorithms:
    a. Logistic Regression
    b. Support Vector Regression

c. Regression trees: Decision tree, random forest
d. Ridge Regression
e. Lasso Regression
f. Clustering/ K-Means
g. K-Nearest Neighbor (KNN)
h. Neural Networks

ME 21014 Theory and Design of Mechanical Systems Laboratory

Teaching Scheme:
Practical: 2hrs/week

Examination Scheme:
Term Work: 50 marks
Practical Exam with oral: 50 marks

Course Outcomes (COs):
At the end of the course students will be able to:

- Approach a design problem involving a complete mechanical system, successfully, taking decisions when there is not a unique answer.
- Use software for analysis and design proficiently.
- Develop industrial drawing with conventions.
- Calculate torque and power for various transmission devices and understand their applications
- Draw various performance curves for the vibration of machine elements

1. Term work shall consist of **"ONE"** design projects. Each project shall consist of two imperial size sheets – one involving assembly drawing with a parts list and overall dimensions and the other sheet involving detailed drawings of individual components. Manufacturing tolerances, surface finish symbols and geometric tolerances should be specified so as to make it a working drawing.
2. A design report giving all necessary calculations of the design of components and assembly should be submitted in a separate file. **Design project** should be in the form of "Design of a complete Mechanical system" comprising of machine elements including gears and bearings. Design data book shall be used, wherever necessary, to select materials and standard components.

Experiments to perform in Laboratory

3. Determinations of torque and power transmitted by various friction drives
4. Determination of unbalanced forces in reciprocation engines
5. Determination of natural frequency of transverse vibrations of a bar.
6. Determination of damping coefficient of torsional vibrations.
7. Determination of node point of two rotor system.
8. Determination of critical speed of shaft of single rotor.

The ORAL shall be based on Term Work.

ME 21015 Steam & Gas Turbine and Combustion Laboratory

Teaching Scheme
Practical: 2 hrs / week

Examination Scheme
Term work: 50 marks
Oral: 50 marks

Course Outcomes (COs):

This course is designed to expose the students to the practical applications of thermodynamics at the end of this course students will be able to:

- Elucidate construction and operational principles of ideal gas and steam nozzle, steam turbine, steam condenser, cooling tower, gas turbine and jet engine
- Apply basic laws of thermodynamics in analysis of thermal systems
- Evaluate performance of boiler.
- Evaluate the thermal performance of steam nozzles, steam turbine, steam condensers, and solar panels.
- Acquire specific knowledge to design solar powered thermal systems
- Compare the application of solid, liquid and gaseous fuels.

Conduct any 8 experiments (any 2 trials on IC engines are mandatory)

1. Study of boilers and boiler mountings and accessories.
2. To determine dryness fraction of steam
3. Trial on boiler to determine boiler efficiency
4. To measure the pressure/Velocity variation of gas or steam in a convergent-divergent nozzle
5. Trial on a condenser to determine the condenser efficiency
6. To determine the conversion efficiency of solar cell/panel
7. Visit to a thermal/solar power plant and submit the visit report.
8. Combustion, performance and emission analysis of diesel engine
9. Combustion, performance and emission analysis of petrol engine
10. Comparative study of CNG and petrol fuelled SI engine
11. Comparative study of biodiesel and diesel fuelled CI engine

Departmental Elective
ME (DE) 21001 Computational Fluid Dynamics and Heat Transfer

Teaching Scheme
Lectures: 3hrs/week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Describe physical interpretation of governing equations.
- Apply the appropriate boundary conditions
- Formulate the discretization of governing equations using fdm and fvm
- Solve the linear algebraic equations for different advection, diffusion schemes.
- Develop simple, simpler algorithm for determination of field variable values.

Unit 1 **(6 hrs)**

Introduction to CFD and principles of conservation:

Computational Fluid Dynamics: History, Necessity, Future Scope, Applications, Various Approaches - Numerical vs Analytical vs Experimental, Modeling vs Experimentation, Reynolds Transport Theorem, Fundamental principles of conservation of mass, linear momentum, energy, General scalar transport equation.

Mathematical classification of Partial Differential Equation, Physical examples of elliptic, parabolic and hyperbolic PDEs.

Unit 2 **(6 hrs)**

Discretization of PDEs – FDM, FVM:

Discretization of Governing Equations, Discretization Approaches - Finite Difference, Finite Volume, System of Algebraic Equations, Numerical Methods, Approximate Solutions for flow field variables, Types of Boundary Conditions, FVM for Diffusion problems - One and Two Dimensional Steady and Unsteady State Diffusion, Unsteady State Diffusion Problems: Implicit, Fully Explicit and Crank-Nicholson scheme.

Unit 3 **(6 hrs)**

Geometry modeling and Grid generation:

Practical aspects of computational modeling of flow domain, grid generation, Types of mesh and selection criteria, Mesh Quality, Key Parameters and their importance.

Unit 4 **(6 hrs)**

FVM for advection diffusion problems:

Discretization of Steady One and Two Dimensional convection diffusion equation, Advection schemes –Extrapolation, interpolation, properties of discretization schemes – Conservativeness, Boundedness, Transportiveness, Accuracy, Central differencing scheme, First Order Upwind scheme, Second Order Upwind scheme, QUICK Scheme, Assessment of Different Schemes.

Unit 5 **(7 hrs)**

Discretization of Navier Stokes equations for incompressible flow (Part 1):
Discretization of the Momentum Equation: Pressure velocity coupling, Checkerboard Pressure field, Concept of Staggered grid, Semi-Explicit Method, Semi-Implicit method for Pressure linked equation (SIMPLE), Relaxation Parameters, SIMPLE Algorithm.

Unit 6 **(7 hrs)**

Discretization of Navier Stokes equations for incompressible flow (Part 2):
Concept of collocated grid system, Semi-Explicit Method, Pressure Correction equation, Semi-Implicit method for Pressure linked equation revised (SIMPLER), SIMPLER Algorithm.

Text Books

- Atul Sharma, introduction to Computational Fluid Dynamics: development, Application and Analysis, John Wiley & Sons Ltd, 2016
- Jiyuan Tu, Guan Heng Yeoh, Chaoqun Liu, Computational Fluid Dynamics – A Practical Approach, Reed Elsevier India Pvt. Ltd, India.
- H.K.Versteeg, W.Malalasekera, An Introduction to computational Fluid Flow (Finite Volume Method), Printice Hall, New Delhi

Reference Books

- J.A. Anderson Jr., Computational Fluid Dynamics-The Basics with Applications,McGraw Hill International Editions, Mechanical Engineering Series, 2004
- Suhas Patankar, Numerical Methods in Fluid Flow and Heat Transfer, Hemisphere Publishing Corporation,1980
- Murlidhar, Sundarrajan, Computational Fluid Flow and Heat Transfer, Narosa Publications
- Chun Yen Chow, An Introduction to Computational Fluid Dynamics, Wiley Publications

Departmental Elective
ME (DE) 21002 Steam Technology

Teaching Scheme
Lectures: 3hrs/week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):
At the end of the course students will be able to:
- Understand and explain working of different boilers and significance of mountings and accessories.
- Use conventional, and modern engineering tools for boiler performance assessment.

- Understand working of simple thermal systems along with energy conservation fundamentals and opportunities.
- Design a steam piping system, its components for a process and also design economical and effective insulation.
- Understand process instrumentation, design and develop controls and instrumentation for effective monitoring of the process.

Pre requisites for the course:
Fundamentals of Thermodynamics, Heat Transfer, Fluid Dynamics, Metallurgy and Fuels and Combustion

Unit 1 **(6 hrs)**

Boilers:
Types, Mountings and Accessories, Combustion in boilers, Feed Water and its quality, Blow down; IBR, Boiler standards

Unit 2 **(7 hrs)**

Piping & Insulation:
Water Line, Steam line design and insulation; Insulation-types and application, Economic thickness of insulation, Heat savings and application criteria, Refractory-types, selection and application of refractory, Heat loss.

Unit 3 **(9 hrs)**

Steam systems:
Properties of steam, Assessment of steam distribution losses, Steam leakages, Steam trapping, Condensate and flash steam recovery system, Steam Engineering Practices; Steam Based Equipments / Systems; Identifying opportunities for energy savings.

Unit 4 **(6 hrs)**

Boiler performance assessment:
Performance Test codes and procedure, Boiler Efficiency, Analysis of losses; performance evaluation of accessories; factors affecting boiler performance.

Unit 5 **(6 hrs)**

Energy conservation and Waste minimization:
Energy conservation options in Boiler; waste minimization, methodology; economical viability of waste minimization

Unit 6 **(5 hrs)**

Instrumentation & Control:
Process instrumentation; control and monitoring

Text Book

- T. D. Estop, A. McConkey, Applied Thermodynamics, Parson Publication
- Domkundwar; A Course in Thermal Engineering; Dhanapat Rai and sons
- R.K. Rajput, Applied Thermodynamics, S. Chand & Company Limited
- Yunus A. Cengel and Boles, "Engineering Thermodynamics ",Tata McGraw-Hill Publishing Co. Ltd

Reference Books

- Book II - Energy Efficiency in Thermal Utilities; Bureau of Energy Efficiency
- Book IV - Energy Performance Assessment for Equipment & Utility Systems; Bureau of Energy Efficiency
- Edited by J. B. Kitto & S C Stultz; Steam: Its Generation and Use; The Babcock and Wilcox Company
- P. Chatopadhyay; Boiler Operation Engineering: Questions and Answes; Tata McGrawHill Education Pvt Ltd, N Delhi

Departmental Elective
ME (DE) 21003 Advanced Manufacturing Technology

Teaching Scheme
Lectures: 3 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):
At the end of the course student will be able to:

- Learn non-conventional processes and their applications
- Learn surface coating processes
- Use rapid prototyping process for product development
- Select appropriate type of plastics and plastics processing method
- Design and fabricate understanding mems systems

Unit 1 **(8 hrs)**

Plastic material and processes:

Different thermosetting and thermoplastic compounds, compression moulding, transfer moulding, injection moulding, film and sheet forming, thermoforming and their applications.

Unit 2 **(6 hrs)**

Rapid prototyping:
Product development cycle and importance of prototyping, types of prototypes-principles and advantages, different types of generative manufacturing process viz. streolithography, FDM and SLS.

Unit 3 **(6 hrs)**

Non-conventional machining processes:
Principles, process parameters and applications of Laser material processing, EDM, WEDM and ECG.

Unit 4 **(6 hrs)**

Special processes:
Principles, silent features, advantages and applications of abrasive floor machining, magnetic abrasive machining, honing, lapping and other super-finishing processes.

Unit 5 **(6 hrs)**

Micro electromechanical Systems (MEMS):
Introduction, micro fabrication for MEMS- bulk micromachining of silicon, surface micromachining of MEMS, wafer bonding for MEMS, LIGA process, micromachining of polymeric MEMS devices, 3D micro- fabrication, materials for MEMS.

Unit 6 **(6 hrs)**

Surface coating:
Principles, elements, process, advantages and surface preparation, physical vapour deposition, chemical vapour deposition, Electroless coating.

Text Books

- B.H. Amsteal, Philip F. Ostwald & Myron L. Begeman, "Manufacturing Processes", John Wiley & Sons, eighth edition.
- P. K. Mishra, Non-Conventional Machining Processes", Narosa Publication
- Amitabha Ghosh, "Rapid Prototyping: Prinicples and Applications in Manufacturing", John Wiley & Sons, Inc.

Reference Books

- Rajaraman, "Computer Oriented Numerical Methods", Prentice Hall of India Delhi.
- T Veerarajan, T Rama Chandran, "Theory and Problems in Numerical Method" Tata McGraw-Hill
- William H. Press, Saul A. Tenkolsky, William T, Vellering, Brain P. Flannery "Numerical Recipes in C", Cambridge University Press.
- G.F. Benidict, "Advanced Manufacturing Processes", Marcel Deker Publisher.
- Willer, "Manufacturing Analysis", "Non-Traditional Machining Processes", SME Publications
- John C. Ion, "Laser processing of engineering materials: principles, procedure and Industrial application", Elsevier
- Chua Chee kai & Leong kah Fai, " Rapid Prototyping : Principles and applications in Manufacturing", Jonn Weiley & Sons, Inc

Departmental Elective
ME (DE) 21004 Operations Research

Teaching Scheme:
Lectures: 3hrs/ week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

At the end of the course student will able to:

- Illustrate the need to optimally utilize the resources in various types of industries.
- Apply and analyze mathematical optimization techniques to various applications.
- Demonstrate cost effective strategies in various applications in industry.
- Demonstrate in use of quantitative techniques in project management.

Unit 1 **(8 hrs)**

Introduction to Operations research and Linear programming problem:

Scope, applications of operations research, phases and models of operations research, advantages and limitations of operations research.

Linear programming problem (LPP)- formulation of linear programming problem (LPP), graphical method of solution, simplex method, artificial variable technique- Big M method and two phase method, duality in LPP, sensitivity analysis.

Unit 2 **(6 hrs)**

Transportation, Assignment and Sequencing problem:

Mathematical formulation of TP, methods to obtain initial basic feasible solution, TP without degeneracy and TP with degeneracy.

Assignment Problem (AP) - Mathematical formulation of AP, comparison with TP, variations of AP, Travelling salesman problem.
Sequencing Problem- Assumptions in sequencing problem, processing of n jobs through two machines, processing of n jobs through three machines, and processing of n jobs through m machines.

Unit 3 **(6 hrs)**

Replacement models:
Introduction, replacement of items that deteriorates- replacement of items whose maintenance and repair cost increases with time, ignoring money value and - replacement of items whose maintenance and repair cost increases with time, considering money value, replacement of items that fail suddenly- group replacement.
Queuing theory- Kendall's notation for representing queuing models, single channel Poisson arrivals with exponential service times, infinite population.

Unit 4 **(6 hrs)**

Games theory:
Minimax (Maximin) criterion for optimality, characteristics of games, dominance principles, 2X2 game- arithmetic and algebraic method, 2Xn and mX2 game-graphical method and method of sub games, 3X3 game- method of matrices, iteration method and applications of games theory

Unit 5 **(6 hrs)**

Inventory models and Simulation:
Need and types of inventory, inventory associated costs, Economic order quantity, Classical EOQ inventory model with uniform demand rate and infinite replenishment. EOQ model with multiple price breaks.
Simulation- Monte Carlo simulation, advantages and limitations of simulation, applications of simulations.

Unit 6 **(6 hrs)**

Network analysis:
Network construction, identification of critical path, various types of floats and their computations, Programme Evaluation and Review Technique (PERT) time calculations, crashing of network, resource scheduling, network updating.

Text Books

- Operations Research- theory, methods & applications, Eighteenth revised edition 2017, S. D. Sharma, Kedar Nath Ram Nath
- Operations Research, Revised and enlarged edition 2012 Prem Kumar Gupta and D S Hira, S Chand & Company Ltd.

Reference Books

- Operations Research-An Introduction, Ninth edition 2014, Hamdy A Taha, Pearson Education India
- Operations Research: Methods and Problems, Maurice Saseini, Arhur Yaspan and Lawrence Friedman, John Wiley and Sons., New York

Departmental Elective (Industry Floated)
ME (DE) 21005 Mathematical Modeling and Analysis of Thermal System

Teaching Scheme:
Lectures: 3hrs/ week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Understand the basic concepts of thermal system.
- Identify various components of thermal system.
- Use various mathematical and numerical relations for modeling, simulation and analysis of the system.
- Optimize the results obtained from the analysis

Unit 1 **(4 hrs)**

Introduction:

Introduction of thermal system, Thermal system design and challenge, Conventional method of thermal design and their limitation, Use of numerical technique in thermal system design.

Unit 2 **(8 hrs)**

Mathematical modeling and Simulation:

Introduction to Mathematical model, System of nonlinear equations, Successive substitution technique and its application in simple thermal simulation problem, Newton Rapson technique for simultaneous nonlinear equations, System of linear equations, Case study

Unit 3 **(10 hrs)**

Simulation and analysis of a heat exchanger and heat exchanger network:

Heat exchanger design, Conventional method and challenges, Concept of overall heat transfer coefficient and LMTD, Type of heat exchangers, Simulation of a single heat exchanger, Thermal simulation using successive substitution and Newton Raphson technique and their application in heat exchanger simulation, Simulation of a multi pass heat exchanger, Simulation of boiler and condenser, Use of discretization in boiler simulation, Discretization in heat exchanger simulation problem, Heat exchanger network and simulation.

Unit 4 **(8 hrs)**

Flow network model:
Flow network model and it's application, Pump characteristics and system characteristics, Concept of resistance, parallel and series combination of resistances, Kirchhoff analogy to solve flow distribution problem, Generalized approach to solve flow problem, Newton Raphson technique to solve flow distribution problem, Two phase flow and Thermosyphon loop, Thermosyphon loop analysis.

Unit 5 **(6 hrs)**

Simulation of thermal power cycle:
Thermal power and refrigeration cycle, Rankine cycle, design and simulation, Gas turbine cycle, Combined cycle, Concept of exergy and exergy analysis, First law and second law efficiency, Refrigeration and heat pump, Simulation of vapor compression cycle

Unit 6 **(4 hrs)**

Optimisation:
Optimisation technique, it’s application in thermal system design.

Text Books

- Design of Thermal System, W F Stoecker, Mc Graw Hill International Edition, Engineering series.

Reference Books

- Basic and Applied Thermodynamics, 2nd Edition, Nag P. K., Tata McGraw-Hill.
- Heat Exchangers: Selection, Rating, and Thermal Design. Sadik Kakaç, Hongtan Liu, Anchasa Pramuanjaroenkij. CRC Press.
- Heat Transfer-A practical approach, Yunus Cengel, McGraw Hill.

Departmental Elective
ME (DE) 21006 Micro Electro Mechanical Systems

Teaching Scheme:
Lectures: 3hrs/ week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Distinguish several classes of MEMS devices from one another and prepare lumped parameter models using tools like MATLAB Simulink.
- Demonstrate the ability to design a simple MEMS device such as cantilevers, fixed-fixed beams, resonator, and comb-drive actuator.
- Design a fabrication process for a given device involving surface micromachining
- Perform basic thermal, structural and electrical simulations using software like ANSYS, COMSOL, etc.
- Propose the use of MEMS devices for a new (out-of-the-box) application.

Unit 1 **(6 hrs)**

Introduction to microsystems:

Overview and motivation of microelectronics manufacture and microsystems technology: Definition, MEMS materials, laws of scaling, the multi-disciplinary nature of MEMS, survey of materials central to micro engineering, applications of MEMS in various industries and commercial examples, Eg., Biomems.

Unit 2 **(6 hrs)**

Micro sensors and Actuators:

Working principle of Microsystems, structural mechanics and lumped modelling, micro actuation techniques, Microsensors and its types pressure transducer, accelerometer, gyroscope, chemical sensors, etc. Microactuators and its types micropump, micromotors, microvalves, microgrippers, and their applications in real systems.

Unit 3 **(6 hrs)**

Fabrication process:

Substrates, single crystal silicon wafer formation, photolithography, ion implantation, diffusion, oxidation, chemical vapour deposition (CVD), physical vapor deposition (PVD), deposition epitaxy, etching process, etc.

Unit 4 **(6 hrs)**

Micro system manufacturing:
Bulk micro manufacturing, surface micro machining, LIGA, SLIGA, Micro system– die preparation, surface bonding, wire bonding, sealing.

Unit 5 **(6 hrs)**

Microsystems design and Simulations:
Design considerations, mechanical design, process design, realization of MEMS components using MEMS specific tools like Coventor Ware/ Intellisuite, etc. and multiphysics simulation tools like ANSYS, COMSOL, etc.

Unit 6 **(6 hrs)**

Microsystems packaging:
Micro system integration and packaging, packaging technologies, assembly of microsystems, reliability in MEMS, packaging materials, die level, device level, system level, packaging techniques, Lab-on-a-chip.

Text Books

- Mohamed Gad – el – Hak, "MEMS Handbook", CRC Press, 2002.
- Rai - Choudhury P. "MEMS and MOEMS Technology and Applications", PHI Learning Private Limited, 2009.
- Sabrie Solomon, "Sensors Handbook," Mc Graw Hill, 1998.
- Marc F Madou, "Fundamentals of Micro Fabrication", CRC Press, 2nd Edition, 2002.

Reference

- Francis E.H. Tay and Choong .W.O, "Micro fluidics and Bio mems application", IEEE Press New York, 1997.
- Trimmer William S., Ed., "Micromechanics and MEMS", IEEE Press New York, 1997.
- Maluf, Nadim, "An introduction to Micro electro mechanical Systems Engineering", AR Tech house, Boston 2000.
- Julian W.Gardner, Vijay K.Varadan, Osama O. Awadel Karim, "Micro sensors MEMS and Smart Devices", John Wiby & sons Ltd., 2001.

Departmental Elective
ME (DE) 21007 Finite Element Analysis

Teaching Scheme
Lectures: 3 hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Develop system level matrix equations from a given mathematical model of a problem following the galerkin weighted residual method or principle of stationary total potential.
- Implement fem, for problems of bars and beams, to obtain the values of the field variable at the global nodes,
- Implement fem, for a 2-dimensional and axi-symmetric problems from structural mechanics to find displacements, stresses and strains, using triangular and quadrilateral element.
- Summarize the sources of errors in implementing fem and suggest remedies to minimize them.
- Determine using fem, parameters of interest for a potential field problem, using triangular and quadrilateral elements.
- Apply fem to estimate the fundamental frequency of natural vibration of bars and beams using the methods mentioned in the curriculum.

Unit 1 **(5 hrs)**

Introduction:

Introduction, An overview of engineering problems and methods for solving them, demonstration by an example – Physical system – Physical model – Mathematical model – Methods for solution – Solution. Need for using numerical method to solve engineering problems-Types of Engineering Analysis.

Unit 2 **(6 hrs)**

Introduction to FEM and 'BAR' problems:

Governing differential equation,787415Introduction to steps of FEM for the problem of finding elongation of an axially loaded bar as an example of a 1-D problem. Step- by-step development of the procedure of Galerkin weighted residual FEM for the bar problem - residual error, weighting function, discretization, elements and nodes, local variables, approximation functions (or shape functions), need for numerical integration and co-ordinate transformation, Gauss-Legendre integration scheme. Process of assembly of local matrix equations into global, solution to the equations, equation solvers.

Unit 3 **(6 hrs)**

FEM for beams:

FE formulation for beams, Governing differential equation, Characteristics of formulation for problems demanding C1 continuity, Hermitian polynomials and shape functions based on them, BEAM element, FEM procedure followed for the beam problems. Computation of derived quantities like strains and stresses from the nodal values of the field variables, Result post-

processing. Finite element formulation using variational and virtual work methods, demonstration for bar and beam problems.

Unit 4 **(7 hrs)**

2-D Problem from structural mechanics:
Introduction to 2-dimensional problem from structural mechanics static analysis, Triangular and quadrilateral elements, Basic concepts of Plain stress and Plain strain. Constant strain triangular element Stiffness Matrix and Equation. Finite element Solution of a plane stress Problem. Higher order elements, iso-parametric elements.

Unit 5 **(6 hrs)**

Potential field problems:
Introduction to potential field problems, examples from structural mechanics - of torsion of non-circular prismatic bars, 2-D steady state heat transfer with convection from surface. Sources of errors, error analysis, remedies to minimize the errors. Application of FEM to Axisymmetric problems, Axisymmetric solids under rotation.

Unit 6 **(8 hrs)**

Eigen-value problems:
Eigen value problems, Mass and stiffness matrices, 2 Dof and 3 Dof spring mass problems. Tranverse vibration of beams .Methods to find Eigen values and Eigen vectors.

Text Books

- Introduction to Finite Element Method By J.N .Reddy.
- Daryl L Logan "Finite Element Method" Thomsom Canada Limited.
- Cook R.D. "Concepts and applications of finite element analysis" Wiley, New York, 1981.

Reference Books

- Bathe K.J., Cliffs, N.J. "Finite element procedures in Engineering Analysis", Englewood. Prentice Hall, 1981.
- Desai C.S. and J.F. Abel "Introduction to the finite element method." New York, Van Nostrand Reinhold, 1972.
- O. P. Gupta, "Finite and boundary element methods in Engineering", Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 2000.
- Chandrupatla and Belegundu "Introduction to finite elements in Engineering", Prentice Hall of India Pvt. Ltd. New Delhi, 2001.

Minor in Product Design and Optimization
ME (MI) 21002 Engineering Design

Teaching Scheme
Lectures: 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Apply design criteria while designing products
- Select appropriate manufacturing process-material combination while designing products.
- Apply design for manufacture & assembly principles for part consolidation & minimizing the cost.
- Design environment friendly products.
- Use quality assurance principles and control charts for mass manufacturing processes.

Unit 1 **(10 hrs)**

Design criteria:

Introduction to strength, rigidity & fracture considerations in design.

Unit 2 **(6 hrs)**

Engineering materials and their selection:

Engineering materials including metals, non metals, composites & smart materials, properties, nomenclature, selection & application.

Unit 3 **(4 hrs)**

Manufacturing processes and compatibility to materials:

Various manufacturing processes with their capabilities, limitations & compatibility with materials.

Unit 4 **(8 hrs)**

Design for manufacture and assembly:

Introduction, Principles and application to product design

Unit 5 **(6 hrs)**

Design for environment:

Techniques to reduce Environmental impact, life cycle assessment, Eco indicator.

Unit 6 **(8 hrs)**

Quality assurance & control charts:
Sampling plans, control charts, six sigma quality concepts, Robust design

Text Books

- A. K. Chitale, R. C. Gupta Product Design and Manufacturing ,PHI Publication, 2013

Reference Books

- Fiksel J., (Ed) Design for Environment, McGraw-Hill, New York, 1996.
- David G. Ullman , the mechanical Design Process, McGraw-Hill, New York, 1992
- Roland Engene Y., Inetoviez, New Product Development: Design & Analysis, John Wiley and Sons Inc., N.Y. 1990.
- Bill Hollins, Stwout Pugh, Butterworth, Successful Product Design by London 1990.

Honor in Hybrid and Electrical Vehicles
ME (HO) 21004 Automotive Mechatronics

Teaching Scheme
Lectures: 3 hrs / week

Examination Scheme
Mini project: 40 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):
At the end of the course students should be able to:

- Understand the basic components of mechatronics used in automobiles and its control system.
- Learn the working principle of sensors, actuators used in automobiles.
- Identify locations of various sensors and actuators in automobiles and its necessity.
- Learn the layout, components and working of electronic engine control system.
- Analyze smart vehicle motion controls, suspensions, telematics smart mechatronic systems for occupant protection and diagnostics in automobiles.
- Apply machine learning (ml), reinforcement learning (rl), and deep learning (dl), soft computing, open source software and hardware, machine vision for automobiles

Unit 1 **(8 hrs)**

Introduction of automotive mechatronics, sensors and actuators:
Introduction to mechatronics: Motivation, Structures, Characteristics, and Functions of Mechatronics Systems, Components of Mechatronics Systems (Motors, Actors, Valves, Pumps, Sensing Technologies, Signal- & Data Processing, Control Systems)
Sensors: Acceleration, Angular rate, Air flow, Air pressure, Ambient light, Antennas, Crankshaft/Camshaft position, Distance – Acoustic, Distance – Optical, Distance – RADAR, Fluid

level, Fluid pressure, Force and Load, Fuel Type, Infrared imaging, Knock sensor, Microphone, Optical imaging, Oxygen sensor, Position, Rain sensor, Temperature, Torque, Vehicle speed, Wheel speed

Actuators: Airbag inflators, Motors - DC Brushed, DC Brushless, AC, Stepper, Servo, Spark plugs, Speakers, Solenoids, Engine Control Actuators, Fuel Injection, Exhaust Gas Recirculation Actuator, Variable Valve Timing, VVP Mechanism Model, Ignition System, Ignition Coil Operations

Unit 2 **(6 hrs)**

Signal communication & Data acquisition:

Introduction to Signal Communication & Types-Synchronous, Asynchronous, Serial, Parallel; Dedicated Short Range Communications, Automotive Data Communication Buses, CAN (Controller Area Network), LIN (Local Interconnect Network), FlexRay, MOST (Media Oriented Systems Transport), Ethernet, Signal collection, conditioning, ADC and DAC, processing, sampling, aliasing, sample and hold circuit, Interfacing of Sensors / Actuators to Data Acquisition system

Unit 3 **(6 hrs)**

Electronic engine control:

Motivation for Electronic Engine Control, Exhaust Emissions, Fuel Economy, Electronic Engine Control system, Inputs to Controller, Output from Controller, Exhaust Catalytic Converters, Oxidizing Catalytic Converter, The Three-Way Catalyst, Electronic Fuel-Control System, Engine Control Sequence, Open-Loop Control, Closed-Loop Control, Analysis of Intake Manifold Pressure, Measuring Air Mass, Influence of Valve System on Volumetric Efficiency, Idle Speed Control, Electronic Ignition

Unit 4 **(6 hrs)**

Vehicle motion controls, suspensions and telematics:

Adaptive Cruise Control Systems, Stepper Motor-based Actuator Electronics, ABS system with layout and working, Autonomous Emergency Braking Systems, Active Yaw Control, Electronic control of suspension –Damping control (Active Suspension Systems), Driver state monitoring (DSM), Supplementary Restraint, System of air bag, seat belts, Vehicle security systems alarms, vehicle tracking system, Collision avoidance, Radar warning system, Introduction to Global Positioning Systems, Lane Departure Warning System, Tire Pressure Monitoring System, Tyre-Slip Controller, Electronic Suspension System, Electronic Steering Control, Telematics, GPS Navigation, The GPS System Structure

Unit 5 **(8 hrs)**

Smart mechatronic systems for occupant protection and diagnostics:
Accident Recorders, Active Vibration Control, Adaptive Front Lighting, Airbag Deployment Systems, Battery Management System, Blind Spot Detection, Cabin Environment Controls, Driver Alertness Monitoring, Auto-Dimming Mirrors, Convertible Top Control, Cylinder Deactivation Systems, Seat Position Controls, Electronic Stability Control, Electronic Toll Collection, Entertainment Systems, Event Data Recorders, Head-Up Displays, Hill Hold Control, Idle Stop-Start Systems, Instrument Clusters, Intelligent Turn Signals, Interior Lighting Control, Lane Departure Warning Systems, Lane Keeping Assist, Night Vision Systems, Parental Controls, Parking Systems, Rear-View Camera Systems, Precrash Safety, Remote Keyless Entry Systems, Security Systems, Tire Pressure Monitoring Systems, Traction Control, Traffic Sign Recognition Systems, Transmission Control, Windshield Wiper Controls, Active Exhaust Noise Cancellation, Active Cabin Noise Suppression, Service Bay Diagnostic Tool, On-board Diagnostics, Model-Based Sensor Failure Detection, Diagnostic Fault Codes, Model-Based Misfire Detection System

Unit 6 **(6 hrs)**

Contemporary topics:
Soft computing methods in automotive technology, applications of open source software and hardware, machine vision for automotive, Autonomous vehicles, key concepts of the perception-planning-control pipeline for autonomous driving (AD); key concepts of machine learning (ML), especially reinforcement learning (RL), and deep reinforcement learning (DRL)

Text Books

- Automotive Mechatronics: Automotive Networking, Driving Stability Systems, Electronics (Bosch Professional Automotive Information), by KonradReif, Springer Fachmedien Wiesbaden, 2014.
- Automobile Electrical & Electronic Equipments -Young, Griffitns -Butterworths, London.
- Understanding Automotive Electronics, Wiliam B. Ribbens, 5th Edition, Newnes, Butterworth–Heinemann.
- Diesel Engine Management by Robert Bosch, SAE Publications, 3rd Edition, 2004
- Gasoline Engine Management by Robert Bosch, SAE Publications, 2nd Edition, 2004
- Understanding Automotive Electronics –Bechfold SAE 1998
- Automobile Electronics by Eric Chowanietz SAE.
- Fundamentals of Automotive Electronics -V.A.W.Hilliers -Hatchin, London

Reference Books

- Automotive Computer & Control System –Tomwather J. R., Cland Hunter, Prentice Inc. NJ
- Automotive Computers & Digital Instrumentation –Robert N. Brandy, Prentice Hall Eaglewood, Cliffs, NJ
- The Fundamentals of Electrical Systems -John Hartly -Longman Scientific & Technical

- Automobile Electrical & Electronic Systems –TomDenton, Allied Publishers Pvt. Ltd.
- Anderson, J. M., Nidhi, K., Stanley, K. D., Sorensen, P., Samaras, C., &Oluwatola, O. A. (2014). Autonomous vehicle technology: A guide for policymakers. Rand Corporation.
- James D. Halderman, Advanced Automotive Electricity and Electronics, Pearson, 2013.
- Tom Denton, Advanced Automotive Fault Diagnosis, Routledge, 2006.
- Nicolas Navet, Francoise Simonot-Lion, Automotive Embedded Systems Handbook, CRC Press, 2008

Honor in Thermal Stream
ME (HO) 21005 Micro Fludics

Teaching Scheme
Lectures: 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Summarize the fundamentals of the physics of flows at micro-scale level.
- Apply mathematical model for micro scale flow.
- Understand the fundamentals of capillary flow.
- Explain and apply fundamentals of electrokinetics to the flow problems
- Design components for applications of microfluidics systems

Unit 1 **(6 hrs)**

Introduction:

Origin, Definition, Benefits, Challenges, Commercial activities,Physics of miniaturization, Scaling laws.

Unit 2 **(8 hrs)**

Microscale fluid mechanics:

Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations. Gas and liquid flows, Boundary conditions, Slip theory, Transition toturbulence, Low Re flows, Entrance effects. Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Thermal transfer in microchannels.

Unit 3 **(6 hrs)**

Capillary flows:

Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Lucas- Washburn equation, Interfacial boundary conditions, Marangoni effect.

Unit 4 **(8 hrs)**

Electrokinetics:
Electro hydrodynamics fundamentals, Electro-osmosis, Debye layer, Thin EDL limit, Boltzman ionic distribution, Stokes Einstein equation, Ideal electroosmoticflow, Ideal EOF with back pressure, Osmotic pressure, velocity scale in electroosmosis, Helmholtz-Smoluchowski velocity, Streaming potential, Lenz's Law, Ionic advection, and conduction current, Electroosmotic velocity profile, Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size, Huckel equation

Unit 5 **(6 hrs)**

Microfabrication techniques:
Materials, Clean room, Silicon crystallography, Miller indices, Oxidation, photolithography- mask, spin coating, exposure and development, Etching, Bulk and Surface micromachining, Wafer bonding, Polymer micro fabrication, PMMA/COC/PDMS substrates, micromolding, hot embossing, fluidic interconnections.

Unit 6 **(6 hrs)**

Microfluidics components:
Micropumps, Check-valve pumps, Valve-less pumps, Peristaltic pumps, Rotary pumps, Centrifugal pumps, Ultrasonic pump, EHD pump, MHD pumps, Microvalves, Pneumatic valves, Thermopneumatic valves, Thermomechanical valves, Piezoelectric valves, Microflow sensors, Differential pressure flow sensors, Drag force flow sensors, Lift force flow sensors, Thermal flow sensors, Droplet generators, Kinetics of a droplet, Dynamics of a droplet, In-channel dispensers, T-junction and Cross-junction, Droplet formation, breakup and transport.

Text Books

- Nguyen, N. T., Werely, S. T., Fundamentals and applications of Microfluidics, Artechhouse Inc., 2002.
- Madou, M. J., Fundamentals of Micro fabrication, CRC press, 2002.

Reference Books

- Bruus, H., Theoretical Microfluidics, Oxford University Press Inc., 2008.
- Tabeling, P., Introduction to microfluidics, Oxford University Press Inc., 2005.
- Kirby, B.J., Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices,Cambridge University Press, 2010.
- Colin, S., Microfluidics, John Wiley & Sons, 2009.

Honor in Design Stream
ME (HO) 21006 Fracture Mechanics

Teaching Scheme
Lectures: 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):
At the end of the course students will be able to:

- Predict different modes of failure and differentiate between brittle fracture and ductile fracture.
- Interpret the damage tolerance of a component with a crack by analyzing the problem by methods of energy release rate and stress intensity factor.
- Explore the test methods for determining critical energy release rate, critical stress intensity factor.
- Analyze stress and displacement fields at the tip of edge crack and embedded crack.
- Analyze variable amplitude fatigue in a component when a crack is present in it.
- Estimate crack propagation, and environment assisted cracking along with various crack detection techniques.

Unit 1 **(6 hrs)**

Energy release rate:
Kinds of failure, Brittle and ductile fracture, Modes of fracture failure, Damage tolerance, Grifth's Dilemma, Surface energy, Grifth's realization, Grifth's Analysis, Energy release rate, crack resistance, stable and unstable crack growth, R-curve for Brittle Cracks, Critical Energy Release Rate.

Unit 2 **(6 hrs)**

Stress intensity factor:
Introduction, Stress and Displacement Fields in Isotropic Elastic Materials ,Stress intensity factor, Background for Mathematical Analysis, Westergaard's Approach, Application of the Principle of Superposition, Crack in a Plate of Finite Dimensions, edge cracks, embedded cracks, The Relation between G_I and K_I, critical stress intensity factor, Bending and Twisting of Cracked Plates.

Unit 3 **(6 hrs)**

Crack tip plasticity:
Shape and size of plastic zone, effective crack length, effect of plate thickness, Crack tip opening displacement, Definition of the J-Integral, Path Independence, Stress-Strain Relation,

Relationship between CTOD, K_I and G_I for Small Scale Yielding, Equivalence between CTOD and J.

Unit 4 **(6 hrs)**

Test methods:
Introduction, Test methods for determining critical energy release rate, Test Methods to Determine J_{Ic}, Test Methods to Determine G_{Ic} and G_{IIc}, Determination of Critical CTOD.

Unit 5 **(6 hrs)**

Fatigue failure and environment-assisted fracture:
Introduction, Terminology, S-N Curve, Crack Initiation, Fatigue failure: Crack propagation, effect of an overload, crack closure, variable amplitude fatigue load, Micro mechanisms, Environment-assisted fracture, Environment assisted Fatigue Failure, Major Factors Influencing Environment-assisted Fracture, Test Methods.

Unit 6 **(6 hrs)**

Crack detection techniques:
Introduction, various crack detection techniques, Examination through Human Senses, Liquid Penetration Inspection, Ultrasonic Testing, Radiographic Imaging, and Magnetic Particle Inspection.

Text Books

- Kumar Prashant, "Elements of Fracture Mechanics", Tata McGraw-Hill, 2009.
- Maiti S K, "Fracture Mechanics: Fundamentals and Applications", Cambridge University Press, 2015.

Reference Books

- Brook D, "Elementary engineering fracture mechanics', Springer, 2012.
- Liebowitz H.," Fracture" Volume I to VII, Academic Press Inc., Nov. 1972.
- Nadai A and Hemp W. S., "Theory of fow and fracture of solids", McGraw Hill Book Company, 1950.

Interdisciplinary Open Course-I (IOC)
IOC 21005 Renewable Energy

Teaching scheme
Lectures: 2 hrs/week

Examination Scheme
Internal Test 1: 20 Marks each
Internal Test 2: 20 Marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Understand effect of fossil fuels on global warming and their relative impact on the environment.
- Comprehend the energy scenario of india and the scope of non-conventional energy sources.
- Describe the difference between the non-conventional energy and the renewable.
- Evaluate the performance of the various non-conventional and renewable energy sources.
- Comprehend the recent advancements in energy generations.
- Design skills in non-conventional energy systems and enhance written communication.

Unit 1 **(5 hrs)**

Introduction to energy:

Energy demand growth and supply, Historical perspectives, Fossil fuels: Consumption and Reserves, Environmental impacts of burning fossil fuels, Sustainable development and the role of renewable energy.

Unit 2 **(6 hrs)**

Wind and Hydro power systems :

Atmospheric circulations, factors influencing the winds, wind turbines and types, coefficient of power, torque, Betz limit, Aerodynamic design principle for blades, Introduction to hydro power plant and types, overview of micro, mini and small hydropower plant, types and operational characteristics of hydro turbine

Unit 3 **(6 hrs)**

Bio energy and bio-fuels:

Biomass source and characterization, direct combustion, pyrolysis, mechanism of bio-renewable energy, Gasifiers, updraft gasifier, downdraft gasifier, gasifier-basedelectricity-generating systems, application of biogas slurry in agriculture, bio ethanol for energy generation

Unit 4 **(8 hrs)**

Fuel cells:

Working principle of fuel cells, fuel cell electrochemistry, types of fuel cells: Alkaline fuel, Fuel Cells, Phosphoric acid fuel cell, Solid oxide fuel cell, Molten carbonate fuel cell, Direct methanol Fuel Cell, their applications, relative merits and demerits. Introduction to thermal heat storage.

Unit 5 **(6 hrs)**

Tidal energy:
Tidal power plants: single basin & two basin plants, variation in generation level, Ocean thermal electricity conversion, electricity generation from waves, shortline and floating wave systems.

Unit 6 **(6 hrs)**

Geothermal energy :
Introduction, Geothermal sites in India, high temperature and low temperature sites in India, Conversion technologies, Steam and binary systems, geothermal power plant, open loop and closed loop system

Text Books

- Godfrey Boyle, Renewable energy, Oxford press, 2012
- Twidell J and Weir T., Renewable energy resources, Taylor and Francis, 2006
- Rai G.D., Non-conventional energy sources, Khanna Publication, 2009
- B.H. Khan, Non-conventional energy sources, Mcgrawhill education, 2006.

Reference Books

- Wind Energy Systems by Johnson G. L., Prentice Hall,1985
- Introduction to Hydro Energy Systems: Basics, Technology and Operation by Wagner H. and Mathur J, Springer, 2009.
- Bio-fuels: biotechnology, chemistry, and sustainable development by DM Mousdale, CRC Press, 2008.
- Fuel Cells: From Fundamentals to Applications by S Srinivasan, Springer, 2006.

College of Engineering, Pune

(An Autonomous Institute of Govt. of Maharashtra, Permanently Affiliated to S.P. Pune University)

Department of Mechanical Engineering

Curriculum Structure & Detailed Syllabus (UG Program)

Final Year B. Tech.

(Effective from: A.Y. 2022-23)

Program Education Objectives (PEOs):

I. Cater to the needs of Indian as well as multinational industries

II. Be competent with strong technological background to analyze data, formulate and undertake industrial problems and obtain viable solutions

III. Make successful career in industry / research / higher Studies

IV. Be life-long learning and should be able to work on multi-disciplinary projects

V. Be Competent for effective communication, in management and in professional skills and ethics

Program Outcomes (POs):

On successful completion Graduates will demonstrate:

1. Engineering knowledge
2. Problem analysis
3. Design/development of solutions
4. Conduct investigations of complex problems
5. Modern tool usage
6. The engineer and society
7. Environment and sustainability
8. Ethics
9. Individual and team work
10. Communication
11. Project management and finance
12. Life-long learning

Correlation between the PEOs and the POs

PO→ PEO↓	1	2	3	4	5	6	7	8	9	10	11	12	PSO1	PSO2	PSO3
I	✓		✓		✓	✓	✓				✓		✓		✓
II	✓	✓	✓		✓								✓		
III				✓		✓		✓	✓			✓		✓	✓
IV		✓	✓		✓					✓	✓	✓	✓	✓	✓
V						✓		✓	✓	✓	✓				✓

Programme Specific Objectives (PSOs):

I. Apply concepts of Design, Production and Thermal-fluid sciences to solve engineering problems utilizing advanced technology.

II. Use mechanical engineering software for the design and analysis of mechanical engineering systems/processes.

III. Extend and implement new thoughts on product design and development with the aids of modern CFD and CAD/CAM/CAE tools, while ensuring best manufacturing practices.

List of Abbreviations

Sr. No.	Abbreviation	Stands for:
1	BSC	Basic Science Course
2	DEC	Department Elective Course
3	HSMC	Humanities, Social Sciences including Management courses
4	IFC	Interdisciplinary Foundation Course
5	IOC	Interdisciplinary Open Course
6	LC	Laboratory Course
7	MLC	Mandatory Learning Course
8	PCC	Program Core Course
9	SBC	Skill Based Course

CURRICULUM STRUCTURE OF Final Year B.TECH (Mechanical)

Effective from A. Y. 2022-2023

VII-Semester: [M-Group]: Scheme A

Sr. No	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	MLC		Intellectual Property Rights	1	0	0	0
2	LLC		Liberal Learning Course	1	0	0	1
3	IOC		Interdisciplinary Open Course-II	2	0	0	2
4	DEC		Department Elective-II [Option among minimum 3 courses]	3	0	0	3
5	PCC	ME-22001	Automatic Control System	3	0	0	3
6	PCC	ME-22002	Refrigeration and Air Conditioning	3	0	0	3
7	PCC	ME-22003	CAD and Digital Manufacturing	2	0	0	2
8	LC	ME-22004	Refrigeration and Air Conditioning Lab	0	0	2	1
9	LC	ME-22005	CAD and Digital Manufacturing Lab	0	0	2	1
			Total	**15**	**00**	**04**	**16**
			Total Academic Engagement and Credits	**19**			**16**

- ONE Minor course [To be offered to the Students from Other Departments]
- ONE Honors course [To be offered to Students of Host Department]

VIII-Semester: [M-Group]: Scheme A

Sr. No	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	DEC		Department Elective-III [Option among minimum 3 courses]	3	0	0	3
2	DEC		Department Elective-IV [Option among minimum 3 courses]	3	0	0	3
5	SBC		Major Project	0	0	16	8
			Total	**06**	**00**	**16**	**14**
			Total Academic Engagement and Credits	**22**			**14**

- ONE Minor course [To be offered to the Students from Other Departments]
- ONE Honors course [To be offered to Students of Host Department]

VII-Semester: [M-Group]: Scheme B

Sr. No	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	MLC		Intellectual Property Rights	1	0	0	0

2	LLC		Liberal Learning Course	1	0	0	1
3	IOC		Interdisciplinary Open Course-II	2	0	0	2
4	DEC		Department Elective-II [Option among minimum 3 courses]	3	0	0	3
5	PCC	ME-22001	Automatic Control System	3	0	0	3
6	PCC	ME-22002	Refrigeration and Air Conditioning	3	0	0	3
7	PCC	ME-22003	CAD and Digital Manufacturing	2	0	0	2
8	LC	ME-22004	Refrigeration and Air Conditioning Lab	0	0	2	1
9	LC	ME-22005	CAD and Digital Manufacturing Lab	0	0	2	1
			Total	**15**	**00**	**04**	**16**
			Total Academic Engagement and Credits	**19**			**16**

- ONE Minor course [To be offered to the Students from Other Departments]
- ONE Honors course [To be offered to Students of Host Department]

VIII-Semester: [M-Group]: Scheme B

Sr. No	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	SBC		Internship and Major Project with Industry/Corporate/Academia	0	0	16	8
2	SLC		Massive Open Online Course -I	3	0	0	3
3	SLC		Massive Open Online Course -II	3	0	0	3
			Total	**06**	**00**	**16**	**14**
			Total Academic Engagement and Credits	**22**			**14**

VII-Semester: [M-Group]: Scheme C

Sr. No	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	MLC		Intellectual Property Rights	1	0	0	0
2	LLC		Liberal Learning Course	1	0	0	1
3	IOC		Interdisciplinary Open Course-II	2	0	0	2
4	DEC		Department Elective-II [Option among minimum 3 courses]	3	0	0	3
5	PCC	ME-22001	Automatic Control System	3	0	0	3
6	PCC	ME-22002	Refrigeration and Air Conditioning	3	0	0	3
7	PCC	ME-22003	CAD and Digital Manufacturing	2	0	0	2
8	LC	ME-22004	Refrigeration and Air Conditioning Lab	0	0	2	1
9	LC	ME-22005	CAD and Digital Manufacturing Lab	0	0	2	1
			Total	**15**	**00**	**04**	**16**
			Total Academic Engagement and Credits	**19**			**16**

- ONE Minor course [To be offered to the Students from Other Departments]
- ONE Honors course [To be offered to Students of Host Department]

VIII-Semester: [M-Group]: Scheme C

Sr. No	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	SBC		Internship and Major Project with Non domain organization	0	0	16	8
2	SLC		Massive Open Online Course -I	3	0	0	3
3	SLC		Massive Open Online Course -II	3	0	0	3
			Total	**06**	**00**	**16**	**14**
			Total Academic Engagement and Credits	**22**			**14**

- ONE Minor course [To be offered to the Students from Other Departments]
- ONE Honors course [To be offered to Students of Host Department]

List of Departmental Electives II (Semester VII):

Sr. No.	Course Code	Elective Course	Sr. No.	Course Code	Elective Course
1	ME (DE)-22001	Power Plant Engineering	6	ME (DE)- 22006	Molecular Mechanics and Multi Scale Modeling
2	ME (DE)-22002	Hybrid and Electric Vehicle	7	ME (DE)- 22007	Robotics and Automation
3	ME (DE)-22003	Solar Energy Engineering and Systems	8	ME (DE)- 22008	Industrial Engineering
4	ME (DE)-22004	Integrated Product Design	9	ME (DE)- 22009	Mechatronics and IoT
5	ME (DE)-22005	Failure Analysis and Prevention			

List of Departmental Electives III (Semester VIII):

Sr. No.	Course Code	Elective Course	Sr. No.	Course Code	Elective Course
1	ME (DE)-2200X	Energy Conservation and Management	6	ME (DE)-	Condition Monitoring
2	ME (DE)-2200X	Heating Ventilation Air Conditioning and Refrigeration	7	ME (DE)-	AI & ML For Mechanical Engineers
3	ME (DE)-2200X	Connected and Autonomous Vehicle	8	ME (DE)-	Sensors and Actuators in Robotics Technology
4	ME (DE)-2200X	Computational Convective Heat Transfer	9	ME (DE)-	Project Management
5	ME (DE)-2200X	Mechanics of Composite Materials			

List of Departmental Electives IV (Semester VIII):

Sr. No.	Course Code	Elective Course	Sr. No.	Course Code	Elective Course
1	ME (DE)-	Design of Heat Exchanger	5	ME (DE)-	Mechanical Vibrations and Acoustics
2	ME (DE)-	Introduction to Nuclear Engineering	6	ME (DE)-	Tribology
3	ME (DE)-	Nano Technology in Solar Engineering	7	ME (DE)-	Advanced CAD/CAM
4	ME (DE)-	Fracture Mechanics	8	ME (DE)-	Manufacturing Philosophies

Minor and Honor courses (VII-Semester)

Sr. No.	CourseType	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	Minor: Product Design and Optimization	ME (MI)-XX001	Introduction to Optimization Techniques	3	0	0	3
1	Honor: Hybrid and Electric vehicle	ME (HO)-XX001	Hybrid and Electric Vehicles	3	0	0	3
2	Honor: Thermal Stream	ME (HO)-XX002	Advanced Heat Transfer	3	0	0	3
3	Honor: Design Stream	ME (HO)-XX003	Stress Analysis	3	0	0	3

Minor and Honor courses (VIII Sem)

Sr. No.	CourseType	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	Minor: Product Design and Optimization	ME (MI)-XX002	Introduction to CAD/CAM	3	0	0	3
1	Honors: Hybrid and Electric vehicle	ME (HO)-XX004	Automotive Transmission and Control	3	0	0	3
2	Honor: Thermal Stream	ME (HO)-XX005	Modeling of IC Engines	3	0	0	3
3	Honor: Design Stream	ME (HO)-XX006	Advanced Vibration and Acoustics	3	0	0	3

Interdisciplinary Open Course-II (IOC-II)

Sr. No.	Course Code	IOC-II
1	ME (IOC) XX001	Air Conditioning

Departmental Elective- II
ME (DE) 22001 Power Plant Engineering

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Explain the basic working principles of steam, hydel, diesel, as turbine power plant and boilers.
- Evaluate performance of thermal power plant, hydel power plant, diesel power plant gas turbine power plant.
- Illustrate working principle of diferent types of nuclear power plant.
- Describe working and significance of various non-conventional power plants.
- Evaluate cycle efciency and performance of these power plants.
- Know the costs associated with power generation.
- Evaluate economics of plant selection and generation.
- Appraise safety aspects of power plants.

Unit 1 **(6 hrs)**

Introduction to Power Plants & Boilers:
Layout of steam, hydel, diesel, mhd, nuclear and gas turbine power plants, combined power cycles, comparison and selection, load duration curves, steam boilers and cycles, high pressure and super critical boilers, fluidised bed boilers.

Unit 2 **(6 hrs)**

Steam Power Plant:
Fuel and ash handling, combustion equipment for burning coal, mechanical stokers, pulveriser, electrostatic precipitator, draught,diferent types, surface condenser types, cooling towers.

Unit 3 **(6 hrs)**

Hydel Power Plants:
Hydel power plant, essential elements, selection of turbines, governing of turbines- micro hydel developments.

Unit 4 **(6 hrs)**

Diesel and Gas Turbine:
Types of diesel plants, components, selection of engine type, applications gas turbine power plant, fuels, gas turbine material, open and closed cycles, reheating, regeneration and inter-cooling, combines cycle.

Unit 5 **(6 hrs)**

Other Power Plants:
Nuclear energy, fission, fusion reaction, types of reactors, pressurized water reactor, boiling water reactor, waste disposal and safety. geo thermal, otec, tidal, pumped storage, solar central receiver system.

Unit 6 **(6 hrs)**

Economics of Power Plants:
Cost of electric energy, fixed and operating costs, energy rates, types tarifseconomics of load sharing, comparison of various power plants.

Text Books:

- Arora S.C and Domkundwar S, "A Course in Power Plant Engineering", DhanpatRai, 2016.
- Nag P.K ,"Power Plant Engineering" Third edition Tata McGrawHill,2014.

Reference Books:

- EI-WakilM.M ,Power "Plant Technology," Tata McGraw-Hill 2017.
- K.K.Ramalingam , " Power Plant Engineering ", Scitech Publications, 2015.
- G.R,Nagpal , "Power Plant Engineering", Khanna Publishers 2011.
- G.D.Rai, "Introduction to Power Plant Technology" Khanna Publishers,2015.
- Black & Veatch, "Power Plant Engineering", Springer Science & Business Media, Inc 1996.

Departmental Elective- II
ME (DE) 22002 Hybrid and Electric Vehicle

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:

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

- Apply basic principles of hybrid and electric vehicle to design vehicle.
- Select appropriate cycle source of energy for the hybrid electric vehicle based on driving.
- Analyze the power and energy need of the various hybrid electric vehicle.
- Measure and estimate the energy consumption of the Hybrid Vehicles.
- Evaluate energy efficiency of the vehicle for its drive trains.

Unit 1 **(6 hrs)**

Introduction to Electric Vehicle:

History of Electric Vehicles, Development towards 21st Century, Types of Electric Vehicles in use today – Battery Electric Vehicle, Hybrid (ICE & others), Fuel Cell EV, Solar Powered Vehicles. Motion and Dynamic Equations of the Electric Vehicles: various forces acting on the Vehicle in static and dynamic conditions.

Unit 2 **(6 hrs)**

Induction to Hybrid Electric Vehicle:

Social and environmental importance of hybrid and electric vehicles, impact of modern drivetrains on energy supplies. Hybrid Electric drivetrains: Basic concept of hybrid traction, introduction to various hybrid Drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.

Unit 3 **(8hrs)**

Electric Drive Trains:

Basic concept of electric traction, introduction to various electric drive- train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis. Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency.

Unit 4 **(7hrs)**

Types of Storage Systems:

Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices. Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Calculation for the ratings.

Unit 5 **(7hrs)**

Modelling of Hybrid Electric Vehicle Range:
Driving Cycles, Types of Driving Cycles, Range modelling for Battery Electric Vehicle, Hybrid (ICE & others), Fuel Cell EV, Solar Powered Vehicles. Case study of 2-wheeler, 3-wheeler and 4-wheeled vehicles.

Unit 6 **(7hrs)**

Energy Management Strategies
Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy management strategies. Introduction to various charging techniques and schematic of charging stations.

Reference Books:

- James Larminie, J. Lowry, "Electric Vehicle Technology Explaned", John Wiley & Sons Ltd. 2003.
- M. Ehsani, Y. Gao, S. E. Gay and A. Emadi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design", CRC Press, 2004.
- S. Onori, L. Serrao and G. Rizzoni, "Hybrid Electric Vehicles: Energy Management Strategies",Springer, 2015.
- Iqbal Hussein, "Electric and Hybrid Vehicles: Design Fundamentals", CRC Press, 2003.

List of Open-Source Software/learning website:

- Online course: https://nptel.ac.in/course.html
- Ocw.mit.edu/courses
- https://www.eng.mcmaster.ca/mech/content/electric-and-hybrid-vehicles

Departmental Elective- II
ME (DE) 22003 Solar Energy and Engineering System

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Describe the equipments used for the measurement of solar irradiation
- Estimate the type of solar collector needed for the application

- Evaluate and analyze the performance of solar thermal system utilizing the suitable model
- Apply the concepts of semiconductors on the solar photovoltaic

Unit 1 **(5 hrs)**

Solar radiation and measurement:
Solar constant, spectral distribution and variation of extra terrestrial radiation, definitions of irradiations, solar angles, angles of tracking surfaces, ratio of beam radiation on tilted surface to horizontal surface, shading, short wave and long wave radiation, pyrheliometer and pyranometer, shading ring, solar radiation data, atmospheric attenuation of solar radiation.

Unit 2 **(8 hrs)**

Preliminary heat transferand radiation characteristics:
Basic radiative laws, radiation intensity and flux, relationships among Absorptance, emittance and reflectance, sky radiations, natural convection between flat parallel plates, wind convection coefficient, selective surfaces, mechanism of selectivity, specularly reflecting surfaces, absorption by glazing, optical properties of cover systems, transmittance - Absorptance product

Unit 3 **(6 hrs)**

Non concentrating solar thermal collectors:
Description of flat plate collectors, energy balance of flat plate collector, temperature distribution in flat plate collector, overall heat loss coefficient, effect of dust and shading, liquid heat plate geometries, air heaters, collector characterization, practical considerations for flat plate collectors,

Unit 4 **(7 hrs)**

Concentrating solar thermal collectors:
Concentration ratio, thermal performance of concentrating collector, optical performance of concentrating collectors, optical characteristics of non imaging concentrators, orientation and absorbed energy for CPC collectors, performance of CPC collectors, Ray tracing methods for evaluating concentrators, paraboloidal concentrators, central receiver collectors

Unit 5 **(8 hrs)**

Energy storage and Economics:
Process load and solar collector outputs, energy storage in solar process system, water storage, stratification in storage tanks, phase change energy storage, chemical energy storage.
Cost of solar process system, design variables, economic figures of merit, discounting and inflation, life cycle saving method

Unit 6 **(8 hrs)**

Solar Photovoltaic:

Fundamental of semi-conductor physics, doping, interaction of light and semi-conductors, functioning of solar cells, types of solar cells, efficiency measurements, recent developments in solar cells, Characteristic curves of PV system technology, basics of load calculations, applications of solar photovoltaic.

Text books:

- Duffie, J.A. and Beckmann, W.A., Solar Engineering of Thermal Processes, John Wiley &Sons (2006).
- Sukhatma, S and Nayak, J., Solar Energy Principle of Thermal Collection and Storage, McGraw-Hill (2009).
- Garg, H.P. and Prakash, J., Solar Energy: Fundamentals and Applications, Tata McGraw Hill (2000).

Reference books:

- Kalogirou, A.S., Solar Energy Engineering: Processes and Systems, Academic Press Inc. (2014).
- Goswami, D.Y., Kreith, F. and Kreider J., Principles of Solar Energy, Taylor & Francis (2003).
- Chetan Singh Solanki, Solar photovoltaic fundamental technologies and applications, PHI publications (2015)

Departmental Elective- II
ME (DE) 22004 Integrated Product Design

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:

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

- Identify the needs of the customer while designing a new product or while modifying existing design of a product in the highly competitive, dynamic and customer centered market.
- Convert the needs of customers in technical specifications and constraints of a product.
- Design the products after realizing the importance of creativity.

- Employ the learnings of various rapid prototyping methods and reverse engineering methods for generating and testing the new product designs.
- Apply principles of statistical considerations in design
- Realize the importance of design for manufacture and assembly and apply the principles to the design.
- Utilize the principles of maintenance&reliability for the design.

UNIT 1: **(12 Hrs)**
Need Identification and problem definition, product specification, concept generation and selection, evaluation, creativity methods, Concept testing

UNIT 2: **(8 Hrs)**
Design for manufacture and assembly, robust design , concurrent engineering,

UNIT 3: **(6 Hrs)**
Rapid prototyping and reverse engineering

UNIT 4: **(6 Hrs)**
Statistical considerations in design

UNIT 5: **(4 Hrs)**
Strength based reliability, parallel and series systems

UNIT 6: **(3 Hrs)**
Ergonomics & Human behaviour in Design

Text Books

- Product Design Creativity, Concepts and Usability; Prashant Kumar, PHI Learning Pvt. Ltd. New Delhi, 2012
- "Engineering Design", George E Dieter, McGraw Hill Company, 2000.
- Reverse Engineering an Industrial perspective, Editors: Vinesh Raja, KiranJ.Fernandes, Springer , 2008
- Rapid Prototyping: Laser-Based and Other Technologies Patri K. Venuvinod, Weiyin Ma Springer, 30-Nov-2003
- Design of Machine Elements, V. B. Bhandari , Tata McGraw Hill Publications.2003

Reference Books

- Product Design and Development, Karl Ulrich, Steven Eppinger, 7th edition, McGraw Hill, 2020

Departmental Elective- II
ME (DE) 22005 Failure Analysis and Prevention

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Specify the diverse factors that cause mechanical failures.
- Identify the different facture modes and their characteristics.
- Identify failure mechanisms.
- Apply the procedures to conduct a failure analysis investigation due to different loading conditions.

Unit 1: **(6hrs)**
Introduction to Failure Analysis
Definition of failures, Classification of failures, Instantaneous failures, Cumulative failures, Fundamental causes of failures-Deficiencies in design, Deficiencies in selection of materials, Imperfection in materials, Deficiencies in processing techniques, Errors in assembly, Improper service conditions. Objectives of Failure analysis, Step by step procedure for Metallurgical failure analysis,

Unit 2: **(6hrs)**
Fracture
Details of Fractographic, Crack initiation and propagation in ductile and brittle material, Fracture types, Brittle fractures, Ductile fractures, Fatigue fractures, Cleavage and intergranular fractures, Griffith theory, Irwin's modification, surface and embedded cracks, Surface treatments to minimize the surface cracks, Crack growth mechanism for plane stress and plain strain, Notch sensitivity, stress tri-axiality, Failure due to tension and torsion, Modulus of rupture, stress intensity factor, Fatigue crack growth, striations, identifications and remedies.

Unit 3: **(6hrs)**
Wear Failures
Definition of wear, Types of wear-adhesive wear, Abrasive wear, Corrosive wear, Erosive wear, fretting wear, Fatigue wear, Wear failure mechanisms and Preventive techniques. Failure of fraction surfaces: failure of clutches, Failure of brakes, Failure of seals, Creep failures, Stages of creep, Creep curve, Stress rupture,Failure modes and Preventive techniques of friction surface and Seals.

Unit 4: **(6hrs)**
Environment Induced Failures
Corrosion damage, Forms of corrosion-Uniform attack, Two metal corrosion or galvanic corrosion, Crevice corrosion, Pitting corrosion, Inter-granular corrosion, Selective leaching, Erosion corrosion, Corrosion cracking- Stress Corrosion Cracking, Corrosion fatigue, Hydrogen cracking, Hydrogen degradation, Liquid metal embrittlement, High temperature corrosion, corrosion failure mechanisms and Preventive techniques.

Unit 5: **(6hrs)**
Tools for Failure Analysis

Microscopic examination-Metallurgical Microscope, Scanning Electron Microscope, Transmission Electron Microscope, Physical testing-Tension test, Hardness test, Impact test, Fatigue test Non-Destructive Testing techniques-Magnetic particle inspection, Radiography, Liquid penetrant inspection, Eddy current testing, Ultrasonic testing, Acoustic Emission Testing, Thermography, Chemical analysis- Spectroscopy, Atomic absorption spectroscopy, Atomic emission spectroscopy.

Unit 6: (6hrs)

Problem Solving Techniques and Case Studies

Problem solving tools like Root cause analysis, cause and effect matrix, fishbone diagram, PDCA: Plan-Do-Check-Act Cycle, SCRA: Symptom, Cause, Remedy and Action system for solving acute and/or temporary problems / Quality Story, CEDAC: Cause-and-effect Diagram with Addition of Cards for chronic problems, etc., 8D (8 Disciplines), FMEA, etc.Failure investigations of rotating components- crack shaft, bearing and gears, boiler tube, turbine rotor, blades, aircraft fuselage, fasteners, Failures of cast, forged and welded components, etc.

Text Books

- Charlie R. Brooks and Ashok Chaudhary, Failure Analysis of Engineering Materials, McGraw Hill, New York.
- A.K. Das, Metallurgy of Failure Analysis, McGraw Hill, New York.

Reference Books

- ASM Handbook, Failure Analysis and Prevention, Edited by, ASM Publications, Vol. 11, 2002.
- Colangelo Vito J. and Heiser F., Analysis of Metallurgical Failures, Second Edition, John Wiley & Sons, Inc., 1987.
- Jones D. R. H., Failure Analysis and Case Studies, Elsevier Publications, 1998.
- Donald J. Wulpi, Understanding How Components Fail, ASM international.
- V. Ramachandran, Failure Analysis of Engineering Structures: Methodology and Case Histories, ASM International, Technology & Engineering, 2005.
- Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, John Wiley & Sons, Fifth Edition.
- SAE J1739, “Potential Failure Mode and Effects Analysis in Design (Design FMEA)”

Departmental Elective- II
ME (DE) 22006 Molecular Mechanics and Multiscale Modeling

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Deal with molecular dynamics simulations at the nano-scale level and perform bottom-up approach in an efficient way.
- Perform FEM simulations at macro-scale by using nano-scale mechanical properties.
- Use the knowledge of fracture at nano-scale as well as macro-scale.
- Deal with interdisciplinary field problems, e.g nano-scale MD simulations and macro-scale FEM simulations
- Use the knowledge to explore naturally available hierarchical materials, which outperform artificial materials in terms of mechanical properties
- Apply contents of the lecture to natural as well as artificial materials.

Unit 1(04 Hrs)

Introduction and motivation of multi-scale modelling:
Need of multi-scale modelling, current and potential applications, future scope of multiscale modelling in research and development, challenges.

Unit 2 (08 hrs)

Theoretical background of molecular dynamics:
Basic molecular dynamics algorithm, potential energy, non-bonded interactions: van der Waals interactions, electrostatic interactions, embedded-atom method , Bonded interactions : covalent, Integration Algorithms : verlet Algorithm, velocity verlet Algorithm, predictor-corrector.

Unit 3 (08 hrs)

Common statistical ensembles and temperature couplings:
Common statistical ensembles: microcanonical (NVE); canonical (NVT); Isothermal-Isobaric (NPT), Ensemble: advantages, limitations and usages, Temperature couplings: velocity scaling; Berendsen; Andersen; and Nosé-Hoover, Temperature couplin : advantages, limitations and usages

Unit 4 (08 hrs)

Molecular dynamics simulations and mechanical properties at nanoscale
Initialization: crystal structure, initial atom velocities, Energy minimization: Steepest descent (SD), conjugate gradient (CG), Newton-Raphson, Equilibration : different types of equilibration, importance, influence on the output , Extration of mechanical properties : Virial stress, force, response functions (for example, constant volume heat capacity), entropic properties, radial distribution function , Non-equilibrium molecular dynamics : Calculate viscosity, thermal conductivity

Unit 5 (06 hrs)

Theoretical background of continuum mechanics:

Concept of a continuum, kinematics : motion and deformation , Governing equations Simple examples : tensile, compression, bending tests.

Unit6 **(06 hrs)**

Multiscalemodelling: bottom-up approach:
Scale bridging, Bottom-up approach, Applications, Analysis of multi-phasic materials, Examples of advanced materials, understanding of extraordinary properties of hierarchical materials, e.g., spider silk, nacre.

Text Books:

- Frenkel, D., and Smit, B. (2001). Understanding molecular simulation: from algorithms to applications (Vol. 1). Elsevier.
- Rapaport, D. C. (2004).The art of molecular dynamics simulation.Cambridge university press.
- Leach, A. R., and Leach, A. R. (2001). Molecular modelling : principles and applications. Pearson education

References:

- Allen, M. P. (2004). Introduction to molecular dynamics simulation. Computational soft matter : from synthetic polymers to proteins, 23(1), 1-28.
- Engquist, B., Lötstedt, P., Runborg, O. (Eds.). (2009). Multiscalemodeling and simulation in science (Vol. 66). Springer Science Business Media.
- Patil, S. P., Heider, Y., Padilla, C. A. H., Cruz-Chu, E. R., and Markert, B. (2016). A comparative molecular dynamics-phase-field modeling approach to brittle fracture. Computer Methods in Applied Mechanics and Engineering, 312, 117-129.
- Patil, S.P, Shendye, P, and Markert, B. (2020). Molecular dynamics simulations of silica aerogel nanocomposites reinforced by glass fibers, graphene sheets and carbon nanotubes. A comparison study on mechanical properties. Composites Part B Engineering, 107884.
- Raj, M., Patil, S. P., and Markert, B. (2020). Mechanical Properties of Nacre-Like Composites: A Bottom-Up Approach. Journal of Composites Science, 4(2), 35.
- Herman J.Govednik, M. Patil, S.P. and Markert, B. (2020). Molecular Dynamics Simulation Study of the Mechanical Properties of Nanocrystalline Body-Centered Cubic Iron. Surfaces, 3(3), 381–391.

Departmental Elective- II
ME (DE) 22007 Robotics and Automation

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- To understand basic terminologies and concepts associated with Robotics and Automation
- To study various Robotic sub-systems and Automation systems
- To study kinematics and dynamics to understand exact working pattern of robots
- To study the associated recent updates in Robotics and Automation

Unit 1 **(5 hrs)**

Introduction:
Basic concepts such as Definition , three laws, DOF, Misunderstood devices.....etc. , Elements of Robotic Systems i.e. Robot anatomy, Classification, Associated parameters i.e. resolution, accuracy, repeatability, dexterity, compliance, RCC device, ..etc,

Automation:
Concept, Need, Automation in Production System, Principles and Strategies of Automation, Basic Elements of an Automated System, Advanced Automation Functions, Levels of Automations, introduction to automation productivity.

Unit 2 **[05 hrs]**

Robot Grippers:

Types of Grippers , Design aspect for gripper, Force analysis for various basic gripper system.

Sensors for Robots:

Characteristics of sensing devices, Selections of sensors, Classification and applications of sensors.Types of Sensors, Need for sensors and vision system in the working and control of a robot.

Unit 3 **[06 hrs]**

Drives:

Types of Drives, Actuators and its selection while designing a robot system. Types of transmission systems,

Control Systems:

Types of Controllers, Introduction to closed loop control

Control Technologies in Automation:

Industrial Control Systems, Process Industries Verses Discrete-Manufacturing Industries, Continuous Verses Discrete Control, Computer Process and its Forms. Control System Components such as Sensors, Actuators and others.

Unit 4 **[07 hrs]**

Kinematics:

Transformation matrices and their arithmetic, link and joint description, Denavit - Hartenberg parameters, frame assignment to links, direct kinematics, kinematics redundancy, kinematics calibration, inverse kinematics, solvability, algebraic and geometrical methods.

Velocities and Static forces in manipulators:

Jacobians, singularities, static forces, Jacobian in force domain.

Dynamics:

Introduction to Dynamics , Trajectory generations

Unit 5 **[07 hrs]**

Machine Vision System:

Vision System Devices, Image acquisition, Masking, Sampling and quantisation, Image Processing Techniques , Noise reduction methods, Edge detection, Segmentation.

Robot Programming:

Methods of robot programming, lead through programming, motion interpolation, branching capabilities, WAIT, SIGNAL and DELAY commands, subroutines.

Programming Languages:

Introduction to various types such as RAIL and VAL II ...etc, Features of each type and development of languages for recent robot systems.

Unit 6 **[06 hrs]**

Modeling and Simulation for manufacturing Plant Automation:

Introduction, need for system Modeling, Building Mathematical Model of a manufacturing Plant, Modern Tools- Artificial neural networks in manufacturing automation, AI in manufacturing, Fuzzy decision and control, robots and application of robots for automation.

Artificial Intelligence:

Introduction to Artificial Intelligence, AI techniques, Need and application of AI.

Other Topics in Robotics:

Socio-Economic aspect of robotisation. Economical aspects for robot design, Safety for robot and associated mass, New Trends & recent updates in robotics

Text Books:

- John J. Craig, Introduction to Robotics (Mechanics & Control), Addison-Wesley, 2nd Edition, 2004
- Mikell P. Groover., Industrial Robotics: Technology, Programming & Appl., McGraw – Hill International, 1986.
- Shimon Y. Nof , Handbook of Industrial Robotics , , John Wiley Co, 2001.
- Automation, Production Systems and Computer Integrated Manufacturing, M.P. Groover, Pearson Education.
- Industrial Automation : W.P. David, John Wiley and Sons.

Reference Books:

- Richard D. Klafter , Thomas A. Chemielewski, Michael Negin, Robotic Engineering : An Integrated Approach , Prentice Hall India, 2002.
- Handbook of design, manufacturing &Automation : R.C. Dorf, John Wiley and Sons.

Departmental Elective- II
ME (DE) 22008 Industrial Engineering

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Apply the Industrial Engineering concept in the industrial environment.
- Manage and implement different concepts involved in methods study and understanding of work content in different situations.
- Undertake project work based on the course content.
- Describe different aspects of work system design and facilities design pertinent to manufacturing industries.
- Identify various cost accounting and financial management practices widely applied in industries.
- Develop capability in integrating knowledge of design along with other aspects of value addition in the conceptualization and manufacturing stage of various products.

Unit I: Introduction to Industrial Engineering and Productivity

Introduction: Definition and Role of Industrial Engineering, Contribution of Taylor and Gilbreth, Organisation : Concept of organisation, characteristics of organisation, elements of organisation, organisational structure, organisation charts; Types of organisation- formal line, military organisation, functional organization, line & staff organisation; Introduction to management principles, authority and responsibility, span of control, delegation of authority. Productivity : Definition of productivity, Productivity of materials, land, building, machine and

power. Measurement of productivity: factors affecting the productivity, Productivity Models and Index (Numerical), productivity improvement programmers. [6 hrs]

Unit II: Method Study

Work Study : Definition, objective and scope of work-study. Human factors in work-study. Method Study : Definition, objective and scope of method study, activity recording and exam aids, Charts to record moments in shop - operation process charts, flow process charts, travel chart, two handed chart and multiple activity charts. Charts to record movement at work place - principles of motion economy, classification of moments, SIMO chart, and micro motion study. Definition and installation of the improved method, brief concept about synthetic motion study and related Numricals. [6 hrs]

Unit III: Work Measurements

Work Measurements: Definition, objectives and uses; Work measurement techniques. Work sampling - need, confidence levels, sample size determinations, random observation, conducting study with the simple problems. Time study: Definition, time study equipment, selection of job, steps in time study. Breaking jobs into elements, recording information. Rating and standard rating, standard performance, scales of rating, factors affecting rate of working, allowances and standard time determination; Introduction to PMTS and MTM. (Numerical), Introduction to MOST [6Hrs]

Unit IV: Production Planning and Control

Introduction: Types of production systems, Need and functions of PPC, Aggregate production planning, Capacity Planning, ERP: Modules, Master Production Schedule; MRP and MRP-II; Forecasting techniques: Causal and time series models, moving average, exponential smoothing, trend and seasonality; (Numerical). [6 hrs]

Unit V: Facility Design

Facility Location Factors and Evaluation of Alternate Locations; Types of Plant Layout; Computer Aided Layout Design Techniques; Assembly Line Balancing (Numerical); Material Handling: Principles, Types of Material Handling Devices;) Industrial Safety: Safety Organisation, Safety Programme, General Safety Rules. Stores Management.[6 hrs]

Unit VI: Engineering Economy

Engineering Economy and Costing: Elementary Cost Accounting and Methods of Depreciation; Breakeven Analysis (Numerical).Inventory Control: Functions, costs, classifications- Concept of EOQ, purchase model without shortages (Numerical); ABC ,VED and other Analysis [6 hrs]

Text Books:

- M Mahajan, “Industrial Engineering and Production Management”, DhanpatRai and
- Co,2015.

- O. P. Khanna, “Industrial engineering and management”, DhanpatRai publication, ISBN no 13-978- 8189928353, 2010
- MartendTelsang, “Industrial Engineering”, S. Chand Publication, ISBN no 13-978-8121917735,2006.
- Banga and Sharma, “Industrial Organisation & Engineering Economics”, Khanna publication, ISBN no 13- 978-8174090782, 2003.

Reference Books:

- Introduction to Work Study by ILO, Oxford & IBH Publishing Company, New Delhi, Second Indian Adaptation, 2008.
- H.B. Maynard, K Jell, “Maynard‘s Industrial Engineering Hand Book”, McGraw Hill Education.
- Askin, “Design and Analysis of Lean Production System”, Wiley, India
- Zandin K.B., “Most Work Measurement Systems”, CRC Press,2002
- Martin Murry, “SAP ERP: Functionality and Technical Configuration”, SAP Press; 3rd New edition (2010).
- Barnes, “Motion and time Study design and Measurement of Work”, Wiley India

Departmental Elective- II
ME (DE) 22009 Mechatronics and IoT

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Define key elements of mechatronics, principle of sensor and its characteristics
- Utilize concept of signal processing & interface systems such as ADC, DAC, Digital I/O
- Determine the transfer function by using block diagram reduction technique
- Evaluate Poles/Zero, frequency domain parameter for modelling of mechanical system
- Apply the concept of different controller modes to an industrial application
- Develop the ladder programming for industrial application

Unit 1: Introduction to mechatronics, Sensors, Actuators [10 Hrs.]
Introduction to Mechatronics, Need, Applications, building blocks of a typical mechatronic system, Sensors: Types of sensors; Motion Sensors – Encoder (Absolute & incremental), Lidar, Eddy Current, Proximity (Optical, Inductive, Capacitive), MEMS Accelerometer; Temperature sensor – Thermocouple, Thermistor, RTD, Pyrometer, Infrared Thermometer; Force / Pressure Sensors – Strain gauges, Piezoelectric sensor; Flow sensors – Electromagnetic, Ultrasonic, Hot-wire anemometer; Colour sensor – RGB type; Biosensors – Enzyme, ECG, EMG, Selection of Sensors, Actuators: Stepper & Servo motor; Hydraulic and Pneumatic; linear electrical actuators & Selection of Actuators

Unit 2: Introduction to IOT [05 Hrs.]

Introduction of IoT: Definition and characteristics of IoT, Technical Building blocks of IoT, Device, Communication Technologies, Data, Physical design of IoT, IoT enabling technologies, IoT Issues and Challenges- Planning, Costs and Quality ,Security and Privacy, Risks

Unit 3: Data Acquisition and Embedded Systems [10 Hrs.]

Introduction to DAQ, Types, Components of a Data Acquisition System (Sensor, Signal conditioning, processing, controlling and storage/display/action), Data Acquisition: Signal collection, Signal conditioning – Isolation& Filtering, Amplification, Sampling, Aliasing, Sample and hold circuit, Quantization, Analog-to-digital converters (4 bit Successive Approximation type ADC), Digital-to-Analog converters (4 bit R2R type DAC), Data storage, Embedded Systems: Architecture & Characteristics of ES, Types of Embedded systems, Examples of Embedded Systems. Embedded System on Chip (SOC), Components of ES: Hardware and software Hardware components of ES: Power supply: types, characteristics, selection criteria, Processing Unit, Input devices, Output Device.

Unit 4: Communication under IoT [05 Hrs.]

Development boards: Types of boards - Arduino, Raspberry pi, Beagle bone, ESP8266, selection criteria, interfacing of sensors with development boards. Communication under IoT: IoT Protocols: MQTT, CoAP, XMPP and AMQT, IoT communication models, IoT Communication technologies: Bluetooth, BLE, Zigbee, Zwave, NFC, RFID, LiFi, Wi-Fi, Interfacing of wifi, RFID, Zigbee,NFC with development board

Unit 5: PLCs and PID controllers [8 Hrs.]

Introduction to controllers, Need for Control, Proportional (P), Integral (I) and Derivative (D) control actions; PI, PD and PID control systems in parallel form; (Numerical approach), Feed forward anticipatory control, Manual tuning of PID control, Ziegler–Nichols method, Applications: Electro–Hydraulic/Pneumatic Control, Automotive Control

Introduction to PLC; Architecture of PLC; Selection of PLC; Ladder Logic programming for different types of logic gates; Latching; Timers, Counters; Practical examples: Ladder Programming, Functional Block Diagram.

Unit 6: Machine Learning for IOT and IOT Security [07 Hrs.]

Compact fast Machine Learning Accelerators for IOT devices: Edge Computing on IOT Devices, IOT Based Smart Buildings, Distributed Machine Learning, Machine Learning Accelerator, Machine Learning Model Optimization, Least-Squares-Solver for Shallow Neural Network: Introduction, Algorithm Optimization, Hardware Implementation

Securing the Internet of Things & Security Architecture, Security and Vulnerability in the Internet of Things, IoT Node Authentication, Data Protection & Security Requirements in IoT Architecture, Security in Enabling Technologies & Existing Security Scheme for IoT, Introduction to the Use Cases and Emerging Standards and Technologies for Security and privacy in IoT

Text Books:

- William Bolton, Mechatronics: Electronics Control Systems in Mechanical and Electrical Engineering, 6th Ed, 2019
- K.P. Ramchandran, G.K. Vijyaraghavan, M.S. Balasundaram, Mechatronics: Integrated Mechanical Electronic Systems, Willey Publication, 2008
- Bolton, Programmable Logic Controller, 4th Ed, Newnes, 2006
- Lyla B. Das, “Embedded Systems: An Integrated Approach” Pearson

- Raj Kamal, “Embedded Systems: Architecture, programming and Design”, 2nd Edition, McGrawHill, ISBN: 13: 9780070151253
- Raj Kamal, Internet of Things: Architecture and Design Principle” , ISBN-13: 978-93-5260-522-4, McGraw Hill Education (India) 2017
- Securing the Internet of Things, Shancang Li Li Da Xu, Syngress, 2017, Elsevier

References Books:

- Alciatore&Histand, Introduction to mechatronics & measurement systems, 5th Ed, 2019
- Bishop (Editor),Mechatronics – An Introduction CRC 2006
- Mahalik, Mechatronics – Principles, concepts and applications, Tata Mc-Graw Hill
- C. D. Johnson, Process Control Instrumentation Technology, Prentice Hall,New Delhi
- Sriram V. Iyer, Pankaj Gupta, “Embedded Real-time Systems Programming”, Tata McGraw-Hill, ISBN: 13: 9780070482845
- David Hanes, IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things, Cisco Press, ISBN-13: 978-1-58714-456-1, ISBN-10: 1-58714-456-5, 2017
- Hantao Huang, Hao Yu, “Compact and Fast Machine Learning Accelerator for IoTDevices,”Edition: 1st ed. Publisher: Springer Singapore Year: 2019ISBN: 978-981-13-3323- 1

ME 22001 Automatic Control System

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:

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

- Understand the basic contolconcepts, control actions and control systems.
- Find the transfer function for linear, time-invariant mechanical systems and produce analogous electrical, thermal and fluid-flow circuits/systems.
- Analyse quantitatively the transient response of first and second order systems.
- Apply frequency response techniques for stability analysis.
- Study of system in time & frequency domain and understand concept of stability.

(6hrs)

Unit 1: Introduction to Automatic Control System

Need of control system, Manual Vs. Automatic Control System, Advantages of Automatic Control System, Open Loop and Closed Loop Control System and their comparison, Concept of Feedback, Generalized Control System and concept of Transfer Function. Representation of Control System Components: Study of various types of control system components and their mathematical representation used in systems like Mechanical system, Electrical System, Thermal System, Fluid System, Grounded chair representation, Analogies,Block representation of System Elements, Block Diagram Algebra, Block Diagram Reduction

Unit 2: **(6 hrs)**

Transient Response Analysis

Transient and Steady State Response Analysis: Introduction, Various types of standard input signals, First order response to Step, Ramp and Impulse Input, Response of second order system to step input, 8 System specifications, Concept of time constant and its importance in speed response, Effect of Damping ratio on response of Second Order System.

Unit 3: **(6 hrs)**

Control Action and Controllers

Basic types of control action like ON/OFF, Proportional, Integral, Derivative type and their combinations (P,I,PI,PD and PID), Pneumatic and Hydraulic Controllers, Comparison of Pneumatic and Hydraulic Control System. Electrical Systems: Detail study of AC and DC Servo motors, Stepper motors, Servomechanism, Position Control System

Unit 4: **(6 hrs)**

Frequency Response Analysis and Root Locus Technique

Stability analysis, System Stability and Routh's Stability Criteria, Relative Stability Concepts, Polar plots, Phase and Gain Margin, Stability analysis using Bode plots, Simplified Bode plot Root Locus Plots: Definition of Root loci, General Rules for constructing Root Locus, Analysis using Root Locus Plots, Use of MATLAB software in control system.

Unit 5: MATLAB, SIMULINK and LABVIEW **(6 hrs)**

Application of MATLAB in Automatic Control, Dynamic system simulation and PID control using MATLAB and SIMULINK, Introduction to LABVIEW

Unit 6: Digital Control **(6 hrs)**

Introduction to digital/computer based measurement and control systems, Role of computers in process control, Basic components of computer based measurement and control system, sample and hold, ADC /DAC, Architecture of computer based control, Human Machine Interface (HMI), Interfacing computer system with process, Hardware and software of computer based process control system

Text Books :

- Katsuhiko Ogata, "Modern Control Engineering", Prentice Hall of India,5thEdition, 2010.
- Norman S. Nise, "Control Systems Engineering", John Wiley & Sons, 6th Edition, 2010.
- Rudrapratap,"Getting srated with MATLAB",Oxford university press,12 th Edition,2009

Reference Books :

- Francis H. Raven, "Automatic Control Engineering", TMH, 5th edition, 1994.
- Benjamin and C.Kuo, Farid Golnaraghi, "Automatic Control Systems", John Wiley & Sons, 9th Edition, 2014.

ME 22002 Refrigeration and Air Conditioning

Teaching Scheme
Lectures: 2hrs / week
Tutorial: 1 hr / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Understand the working of Vapour Compression refrigeration system
- Design the Vapour Compression refrigeration system for various applications.
- Apply the knowledge of HVAC for multi-pressure systems.
- Able to understand and apply the Psychrometry for air conditioning applications.
- Able to design the duct for various air conditioning systems.

Unit 1: Refrigeration Systems (12 hrs)

Vapour Compression refrigerationsystem: A Refrigerating Machine, Types of refrigeration system, Vapour Compression refrigeration system and thermodynamic cycle, Effect of Evaporator Pressure, Effect of Condenser Pressure, Effect of refrigerant Superheating and Sub cooling, Actual Vapour Compression Cycle (Numerical treatment).
Vapour Absorption Refrigeration Systems: Introduction, working principle, aqua-ammonia, Lithium-bromide and Electrolux Systems.
Multipressure systems: Multi-evaporator Systems, Multistage Systems, Flash Gas Removal, Flash Intercooling, Choice of Intermediate Pressure, Complete Multistage Compression System, Multi-evaporator Systems, Cascade Systems, Solid Carbon Dioxide-Dry Ice, Manufacture of Solid Carbon Dioxide, System Practices for Multistage Systems (Numerical treatment)

Unit 2: Refrigerants (3hrs)

A Survey of Refrigerants, Designation of Refrigerants, Selection of a Refrigerant, Thermodynamic, Chemical, Physical, and safety Requirements, Secondary Refrigerants, Ozone depletion, Global warming, green house effect, Environment friendly refrigerant R134a, R410a, R600a, R290, R32. (Theoretical only)

Unit 3:Refrigerant Compressors (5hrs)

Types of Compressors, Thermodynamic Processes during Compression, Principal Dimensions of a Reciprocating Compressor, Performance Characteristics of a Reciprocating Compressor, Capacity Control of Reciprocating Compressors, Rotary Compressors, Screw Compressors, Centrifugal Compressors, Digital scroll compressors

Unit 4: Condensers, Evaporators and Expansion Devices (6hrs)

Construction and working, Types of condensers, evaporators and expansion devices, Capillary Tube and Its Sizing, pumps, heat exchangers etc. Work done and heat transfer during steady flow processes.

Unit 5: Psychometrics of Air – Conditioning Processes (8hrs)

Properties of moist Air, Working Substance in Air Conditioning, Psychometric Properties, Psychometric Chart, Mixing Process, Basic Processes in Conditioning of Air Psychometric Processes in Air – conditioning Equipment comfort conditions, (Numerical Treatment).

Unit 6:Load Calculation and Applied Psychrometrics(6hrs)
Preliminary Considerations, Internal Heat Gains, System Heat Gains, Break-up of ventilation Load and Effective Sensible Heat Factor, Cooling-load Estimate, Heating – load Estimate, Psychometric Calculations for Cooling, Design of air conditioning equipment, Numerical examples, Introduction to duct design by equal friction method.

Text Books

- Arora R.C., Refrigeration and Air Conditioning, PHI, India
- Dossat Ray J., Principal of Refrigeration, Pearson, India
- Arora C P, Refrigeration and Air Conditioning, Tata McGraw Hill
- Manohar Prasad, Refrigeration and Air-conditioning, Wiley Eastern Limited, 1983
- S.N. Sapali "Refrigeration and Air-conditioning", PHI (Second Edition) 2016

Reference Books

- Threlkeld J.L., Thermal Environmental Engineering, Prentice Hall Inc. New Delhi
- ASHRAE Handbook (HVAC Equipments)
- Stocker W.F. and Jones J.W., Refrigeration and Air-conditioning, McGraw Hill International editions 1982.
- Roger Legg, Air conditioning systems: Design, Commissioning and maintenance
- Shan Wang, Handbook of Refrigeration and Air Conditioning, McGrawHill Publications
- Wilbert Stocker, Industrial Refrigeration, McGrawHill Publications
- Keith Harold, Absorption chillers and Heat Pumps, McGrawHill publications
- ASHRAE, Air Conditioning System Design Manual, IInd edition, ASHRAE.

ME 22003 CAD and Digital Manufacturing

Teaching Scheme
Lectures: 2hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Recall the fundamentals of CAD/CAM
- Apply various 2-D and 3-D geometric transformations
- Represent 2-D/ 3-D analytic and synthetic entities and Compare solid-surface modeling
- Examine CNC program for production of components
- Express the principles and methods of Rapid Prototyping

Unit 1: **(3hrs)**

Fundamentals of CAD/CAM
Product cycle and scope of CAD/CAM/CIM in product cycle, Features of CAD/CAM Hardware and software, selection of software. CAD workstation configurations

Unit 2: (5hrs)
Geometric Transformation
Geometric verses coordinate transformations, 2D geometric transformations, Homogeneous co-ordinate representation, Composite transformations, 3D transformations, Inverse transformations, geometric mapping, Examples of transformation applications in mechanical engineering

Unit 3: (5hrs)
Representation of Curves and surfaces
Introduction to Analytic Curves: line, circle, ellipse, parabola, hyperbola, Synthetic Curves: Hermite Cubic Spline, Bezier Curve, B-Spline curve. Analytic and Synthetic Surface Representation

Unit 4: (4hrs)
Geometric Modeling
2D Vs 3D modeling, Comparison of Wireframe, surface and solid modeling techniques, Geometry Vs Topology, Requirements of Solid Modeling, Solid Modeling Methods: Constructive Solid Geometry (CSG), Boundary Representation (B-rep), etc.

Unit 5: (6hrs)
Computer Numerical Control and Part Programming
Introduction to NC/CNC/DNC machines, Classification of NC systems, Axis nomenclature, Interpolation, features of CNC controllers, Types of CNC machines, Construction features of CNC machines, Manual Part Programming, NC word format, Details of G and M codes, Canned cycles, subroutines and Do loops, Tool radius and length compensations. Exercises on CNC turning center and machining center programming

Unit 6: (3hrs)
Rapid Prototyping and Manufacturing
Introduction to Rapid Prototyping, rapid tooling and rapid manufacturing.Process of rapid prototyping.Different techniques of Rapid prototyping and their applications.

Text Books
- CAD/CAM Theory and Practice, Ibrahim Zeid, Tata McGraw-Hill Publishing Company Ltd.
- Mathematical Elements for Computer Graphics, Dacid F. Rogers, J Alan Adams, McGraw-Hill publishing Company Ltd.

Reference Books
- Geometric Modelling, M.E. Mortenson, Wiley, 2016
- Wolfe & Henderson Computer Aided Design & Manufacturing, Bedworth, McGraw Hill, 2003.

ME 22004 Refrigeration and Air Conditioning Lab

Teaching Scheme
Lectures: 2hrs / week

Examination Scheme
Term work: 50 marks
Practical / Oral: 50 marks

Course Outcomes:
At the end of the course students will be able to:

- Demonstrate the working of domestic refrigerator and Split Air conditioning systems.
- Estimate and analyze the cooling capacity, COP, Power of a VCR system.
- Determine the RSHF using Psychrometric chart.
- Analyze performance of Expansion devices in VCR system
- Estimate the cooling capacity of an evaporative air cooler.
- Demonstrate techniques of estimating building envelop load

List of Experiments:
The students should perform 8 experiments from the following list.

1. Demonstration of a domestic refrigerator along with different auxiliary systems associated with a refrigerator.
2. Trial on Vapour Compression Refrigeration System to determine cooling capacity and coefficient of performance.
3. Trial on Vapour Compression Refrigeration System with R290 as a refrigerant
4. Trial on Air conditioning test rig to determine cooling capacity and COP of VCR system.
5. Trial on Air conditioning test rig to study the psychrometric processes.
6. Trial on an Evaporative Air Cooler
7. Trial on Ice Plant, to determine Coefficient of Performance for ice plant test rig
8. Performance analysis of expansion devices at different operating conditions
9. Study of Vapour Absorption refrigeration Systems.
10. Design of cold storage with process layout
11. Building heat load simulation using suitable software (Trace 700, Energy plus etc.)

ME 22005 CAD and Digital Manufacturing Lab

Teaching Scheme
Lectures: 2hrs / week

Examination Scheme
Term work: 50 marks
Practical / Oral: 50 marks

Course Outcomes:
At the end of the course students will be able to:

- Design parametric models and assembly using CAD software.
- Develop CNC program and simulate.
- Distinguish various 3D printers and able to operate them.

List of Experiments:

1. Use of CAD software to create parametric 3-D models.

2. Use of CAD software to create assembly of components and generate drawings.
3. Manual part programming for CNC lathe machine.
4. Manual part programming for CNC milling machine.
5. Write a program to generate a curve/surface and apply transformation
6. Demonstration of 3D printers and scanners.

Departmental Elective- III
ME (DE) XX001 Energy Conservation and Management

Teaching Scheme
Lectures : 3hrs / week
Tutorial: 1 hr / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

1. Understand and Analyze national and international energy scenario
2. Calculate energy losses in process, equipment and plat etc.
3. Showcase energy conservation opportunities in various mechanical systems and suggest methods for energy savings
4. Analyze the energy data of industries and utilize the technical skills attained to carry out energy accounting and balancing
5. Perform energy audit and use energy management tools
6. Apply practices of energy conservation in various sectors like domestic, Industry and commercial

Unit 1: **(6 hrs)**

Introduction
Global Energy Scenario and Indian Energy Scenario in various sectors and Indian economy. Concerns of Energy Security in India
Basics – Revision of basics of Electrical and Mechanical Engineering relevant to Energy conservation and Management, Definitions of units, conversions in commercial practices Sankey Diagrams, Specific Energy consumption

Unit 2: **(6 hrs)**

Economic Analysis
Simple Payback Period, Return on Investment, Dynamic value of money, Discount Rate Cash flow, Time value of money, Formulae relating present and future cash flow - single amount, uniform series; Payback period; Return on Investment (ROI); Life Cycle cost. Costing of Utilities- specific costs of utilities like; all fuels stream, compressed air, electricity, water etc.

Unit 3: **(6 hrs)**

Energy Conservation Opportunities in Mechanical Systems
Compressed air systems, Refrigeration and air-conditioning system and water systems, Elementary coverage of Energy conservation in pumps and.
Cogeneration-concept, options(steam/gas, turbine/DCT-based), Selection criteria,

Unit 4: (6 hrs)

Energy Conservation Opportunities in Electrical Systems
Electric System Demand control, Demand Side Management (DSM), Power Factor Improvement, benefits and ways of improvement, Load scheduling, Electric motors, losses, efficiency, energy-efficient motors, motor speed control, variable speed drive. Lighting: Illumination levels, fixtures, timers, energy efficient illumination.

Unit 5: (6 hrs)

Energy Audit:
Energy Auditing Elements and concepts, Types of energy audits, methodology, Instruments used in energy auditing; Portable and On-line instruments; Role of Non Conventional Energy Sources in Energy Conservation; Need and Kyoto Protocol, Carbon Credits and Clean Development Mechanism (CDM).

Unit 6: (6 hrs)

Energy conservation in Buildings, Heating, Ventilation and Air Conditioning System,
Energy conservation in Boilers, Performance testing, efficiency and energy conservation opportunities
Energy conservation in Steam Systems– Aspects of steam distribution, Steam Traps, Condensate and Flash-steam utilization, Energy conservation opportunities

Text Books

- Energy Manager Training Manual (4 Volumes) available at a website administered by Bureau of Energy Efficiency (BEE), a statutory body under Ministry of Power, Government of India.
- S Rao and B BParulekar ," Energy Technology" Khanna Publishers, 2012
- K. V. Sharma, P. Venkataseshaiah, "Energy Management and Conservation", I.K. International Publishing House Pvt. Limited, 2011

Reference Books

- Witte. L.C., P.S. Schmidt, D.R. Brown, "Industrial Energy Management and Utilization" Hemisphere Publication, Washington, 1988
- D.A. Reay, "Industrial Energy conservation: A handbook for engineers and managers", Pergamon Press, 1979
- Patrick Steven R., Patric Dale R. and Fordo Stephen : Energy conservation Guide book, The Fairmont Press Inc.7, 1993

- Albert Thumann, “Plant Engineers and managers Guide to Energy conservation”, The Fairmont Press, 2010
- WR Murphy and G McKay, “Energy Management”, Butterworth Heinemann, Elsevier, 1982
- Frank Kreith & D. Yogi Goswami, “Energy management and conservation handbook”, CRC Press, Tailor and Francis Group, 2008

Departmental Elective- III
ME (DE) XX001 Heating Ventilation Air Conditioning and Refrigeration

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Determine the performance parameters of trans-critical & ejector refrigeration systems
- Estimate thermal performance of compressor, evaporator, condenser and cooling tower.
- Describe refrigerant piping design, capacity & safety controls and balancing of vapour compressor system.
- Explain importance of indoor and outdoor design conditions, IAQ, ventilation and air distribution system.
- Estimate heat transmission through building walls using CLTD and decrement factor &time lag methods with energy-efficient and cost-effective measures for building envelope.
- Explain working of types of desiccant, evaporative, thermal storage, radiant cooling, clean room and heat pump air-conditioning systems

Unit 1 **(5hrs)**

Advanced Vapour Compression Cycles:
Review of vapour compression cycle, Trans-critical cycle and their types, Ejector refrigeration cycle and their types. Presentation of cycle on P-h and T-s chart.Analysis of cycles.

Unit 2 **(8hrs)**

Thermal Design of Refrigeration System Components:
Characteristic curves of reciprocating & Centrifugal compressors, sizing of reciprocating compressor, Performance analysis of Dx evaporator, air-cooled condenser, and shell & tube condenser. Operating Characteristics of expansion device, Liquid Charge in the Sensing Bulb,

Hunting of Thermostatic Expansion Valve. Cooling Tower: Types & analysis of cooling towers, cooling tower thermal performance, tower efficiency

Unit 3 **(5hrs)**

Practical Aspects of Vapour Compression System:
Refrigerant Piping : Copper Tubing, Piping Design for Reciprocating Refrigeration Systems, Size of Copper Tube, Refrigeration Load, and Pressure Drop, Sizing Procedure, Suction Line, Discharge Line (Hot-Gas Line), Liquid Line
Safety Controls: Low-Pressure and High-Pressure Controls. Low-Temperature Control, Frost Control, Oil Pressure Failure Control. Motor Overload Control.
Vapour compression system balance: Performance characteristics of the condensing unit & Compressor-capillary tube.

Unit 4 **(8hrs)**

Ventilation and Infiltration:
Basic parameters, factors affecting thermal comforts, Comfort-Discomfort Diagrams, Indoor Temperature, Relative Humidity, and Air Velocity,
Indoor Air Quality: Indoor Air Contaminants, Basic Strategies to Improve Indoor Air Quality, Fresh Air Requirements for Occupants, The use of outdoor weather data in Design, Outdoor Weather Characteristics and Their Influence
Ventilation for cooling: Natural ventilation, mechanical ventilation
Space air distribution: Design of air distribution systems, Types of air distribution devices, Airflow patterns inside conditioned space, stratified mixing flow, Cold air distribution, Displacement flow: Selection of supply air outlets.

Unit 5 **(8hrs)**

Heat Load Estimation in Building Structures:
Solar radiation, Heat gain through fenestrations, Space load characteristics, cooling load and coil load calculations, Overall heat transmission coefficient, air spaces, sol-air temperature, Decrement factor & time lag method, Equivalent Temperature Differential (ETD), Total heat balance. Energy-efficient and cost-effective measures for building envelope, Concept of ECBC, Computerized cooling load calculations, Simulation of psychrometric processes, Simulation of air flow in AC systems.

Unit 6 **(6hrs)**

Advanced Air-conditioning Systems:
Desiccant-Based Air Conditioning Systems : Introduction, Sorbents & Desiccants, Dehumidification, Liquid Spray Tower, Solid Packed Tower, Rotary Desiccant Dehumidifiers, Hybrid Cycles, Solid Desiccant Air-Conditioning, Solar Vapour Compression Refrigeration System Radiant cooling, Performance Metrics Testing Standards (Theoretical treatment).

Text Books

- Arora R.C., Refrigeration and Air Conditioning, PHI, India
- Dossat Ray J., Principal of Refrigeration, Pearson, India
- Arora C P, Refrigeration and Air Conditioning, Tata McGraw Hill
- Manohar Prasad, Refrigeration and Air-conditioning, Wiley Eastern Limited, 1983
- S.N. Sapali "Refrigeration and Air-conditioning", PHI (Second Edition) 2016

Reference Books

- Threlkeld J.L., Thermal Environmental Engineering, Prentice Hall Inc. New Delhi
- ASHRAE Handbook (HVAC Equipments)
- Stocker W.F. and Jones J.W., Refrigeration and Air-conditioning, McGraw Hill International editions 1982.
- Roger Legg, Air conditioning systems: Design, Commissioning and maintenance
- Shan Wang, Handbook of Refrigeration and Air Conditioning, McGrawHill Publications
- Wilbert Stocker, Industrial Refrigeration, McGrawHill Publications
- Keith Harold, Absorption chillers and Heat Pumps, McGrawHill publications
- ASHRAE, Air Conditioning System Design Manual, IInd edition, ASHRAE.

Departmental Elective- III
ME (DE) XX001 Connected and Autonomous Vehicle

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- To know about smart vehicles of today transport
- To understand inter and intra communication for automotive engineering
- To understand vehicular data application and standards
- To understand various levels of Autonomous Driving as per SAE Classification
- To understand the autonomous vehicles & its subsystems.

UNIT 1

Smart Vehicle in Today Transport:
Sensors applications to traffic management, street types and functions, traffic management canters, Inter-vehicle communications: Cooperate driving: Accident driving, frontal collision, prevention, hazards warning, road departure and speed alert, consumer assistance, Traffic information, mobile & multimedia services, smart parking, evolving smart vehicle, microprocessors and algorithm for smart vehicles.

UNIT 2

Basic of Vehicular Communication:
Fundamental concepts, Frequency, bandwidth, power measurement, signal-to-noise ratio, transmission rate constraints, radio-frequency spectrum allocation, RADAR: operation and types, forward radar, side radar, Wireless networking: transmitter and receiver, GPS, cellular transmission, Data recorder, IEEE Wireless LANs & IEEE standards.

UNIT 3
Intra-Vehicle & Inter-Vehicle Communication:
Intra-vehicle communication: Wired communications, Network comparison, LIN, CAN, FlexRay, MOST & applications of different communication protocols, Wireless Communications: Bluetooth, evolution, classes, operation, spectrum utilization, operational modes, and vehicle applications. Inter-vehicle communication: Adhoc Networking, communication technologies, vehicle frequency utilization for different devices, Infrastructure-to-vehicle communication, vehicle-to-vehicle communication.

UNIT 4

Vehicular data application & mobility control:
Security threats, privacy threats, basic data security capabilities, cryptographic mechanism: Introduction, categories of cryptography mechanism, Dedicated Short Range Communication for Vehicles, Intelligent Transportation System: requirement for public, transport vehicle operation in India, Standards: AIS 140, IEEE 1609, CVRIA.

UNIT 5

Autonomous Vehicles:
Overview of autonomous vehicles, performance requirement, Levels of Autonomous driving-SAE J3016, Autonomous Driving in political, social and historical contexts, research related to autonomous vehicles, national & international legislations, Evolution of ADAS (Advanced Driver Assistance System),Operational Design Domain (ODD), Object and Event Detection and Response (OEDR),Location & Mapping System, Sensor Fusion, sensor integration architecture, multiple sensor fusion, Decision Making in Autonomous systems, Autonomous vehicles control systems.

Text Books:

1. Luca Delgrossi, Tao Zhang, “Vehicle Safety Comminications- Protocols, Security, and Privacy”, John Wiley & Sons, Inc., 2012.
2. Syed FarazHasan, NazmulSiddique and ShyamChakraborty, “Intelligent Transportation Systems-802.11-based Vehicular Communications” Springer International Publishing AG, 2018.
3. Gilbert Held, “Inter- and Intra-Vehicle Communications”, Auerbach Publications, 2008.
4. Hong Cheng, “Autonomous Intelligent Vehicles Theory, Algorithms, and Implementation”, Springer London Dordrecht Heidelberg New York, 2011.

5. Markus Maurer, J. Christian Gerdes, Barbara Lenz, Hermann Winner, “Autonomous Driving Technical, Legal and Social Aspects”, Springer-Verlag GmbH Berlin Heidelberg, 2015.

Reference Books:

1. Fei Hu, “Vehicle-to-Vehicle and Vehicle-to-Infrastructure Communications”, CRC Press, Taylor & Francis Group, 2018.
2. Lawrence A. Klein, “ITS Sensors and Architectures for Traffic Management and Connected Vehicles”, CRC Press, Taylor & Francis Group, 2018.
3. NicuBizon, Lucian Dascalescu and NaserMahdaviTabatabaei, “Autonomous Vehicles-Intelligent Transport Systems and Smart Technologies”, Nova Science Publishers, 2014.
4. Ronald K. Jurgen, “Autonomous Vehicles for Safer Driving”, SAE International, 2012.

Departmental Elective- III
ME (DE) XX001 Computational Convective Heat Transfer

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Anticipate and describe the consequence of convective heat transfer in thermal analysis of engineering systems.
- Formulate, and evaluate convective heat transfer solution for laminar internal, and external flow.
- Formulate, evaluate and develop convective heat transfer solution for natural Convection heat transfer from various geometries.
- Formulate, evaluate and develop convective heat transfer solution for turbulent convection.
- Model Convective heat transfer for internal flow and external flow under different conditions using commecercial software.

Unit 1 **(5 hrs)**

Governing equations:
Different Convective Modes, governing Equations: Continuity, momentum and energy Equations, thermal boundary layer, boundary layer approximations to momentum and energy, forced convection: low Prandtl number over a flat plate.

Unit 2 **(7 hrs)**

Laminar external flow and heat transfer:
Similarity solutions for flat plate - blasius solution, flows with pressure gradient - Falkner-Skan and Eckert solutions, and flow with transpiration
Integral method solutions for flow over an isothermal flat plate, flat plate with constant heat flux and with varying surface temperature - Duhamel's method, flows with pressure gradient - Von karman-Pohlhausen method.

Unit 3 **(6 hrs)**

Laminar internal flow and heat transfer:
(a) Exact solutions to n-s equations for flow through channels and circular pipe, fully developed forced convection in pipes with different wall boundary conditions, forced convection in the thermal entrance region of ducts and channels (Graetz solution), heat transfer in the combined entrance region, (b) Integral method for internal flows with different wall boundary conditions.

Unit 4 **(6 hrs)**

Natural convection heat transfer:
Governing equations for natural convection, Boussinesq approximation, Dimensional Analysis, Similarity solutions for Laminar flow past a vertical plate with constant wall temperature and heat flux conditions, Integral method for natural convection flow past vertical plate, effects of inclination, Natural convection in enclosures, mixed convection heat transfer past vertical plate and in enclosures.

Unit 5 **(7 hrs)**

Turbulent convection:
Governing equations for averaged turbulent flow field (RANS),analogies between heat and mass transfer (Reynolds, Prandtl-Taylor and von Karman Analogies), turbulence models (Zero, one and two equation models), turbulent flow and heat transfer across flat plate and circular tube, turbulent natural convection heat transfer, empirical correlations for different configurations.

Unit 6 **(5 hrs)**

Modelling of Convective heat transfer
Tutorials on modelling convective heat transfer process for internal flow through circular tubes under constant wall temperature, constant heat flux conditions. Modelling of natural convection from heated surfaces, flat plates, spheres etc. at different orientations.

Textbooks:

- Convective Heat and Mass Transfer, 4th Edition by W. Kays, M. Crawford and B. Weigand, McGraw Hill International, 2005.
- Convective Heat Transfer, 2nd Edition by S.Kakac and Y. Yener, CRC Press, 1995.
- Convection Heat Transfer, 3rd Edition by A.Bejan, John Wiley, 2004
- H. K. Versteeg and W. Malalasekera, "An Introduction to Computational Fluid Dynamics: The Finite Volume Method", Longman Scientific & Technical, 1995.

1.

References:

- Fundamentals of Heat and Mass Transfer, 7th Edition by F.P. Incropera and D. Dewitt, John Wiley, 2011.
- Boundary Layer Theory, 8th Edition by H.Schlichting and K. Gersten, Springer-Verlag, 2000.

Departmental Elective- III
ME (DE) XX001 Mechanics of Composite Materials

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Differentiate the basic concepts and difference between composite materials with conventional materials.
- Determine role of constituent materials in defining the average properties and response of composite materials on macroscopic level.
- Knowledge for finding failure envelopes and stress-strain plots of laminates.
- Utilize subject knowledge using computer programs to solve problems at structural level.

Overview:
In pursuit of increasing the efficiency of structures use of composite materials is increased. To understand the role of composite materials for replacement of conventional materials, knowing mechanics of composite materials is essential. After understanding this subject you will be able to start stress and strength analysis of any composite structures using FEA (Finite Element Method) based software. Pre-requisite for this course is basics of Solid Mechanics.

Unit 1. Introduction [03 hrs]
Definition and characteristics, Overview of advantage and limitations of composite materials, Significance and objectives of composite materials, Science and technology, current status and future prospectus

Unit 2. Basic Concepts and Characteristics [04 hrs]

Structural performance of conventional material, Geometric and physical definition, Material response, Classification of composite materials, Scale of analysis; Micromechanics, Macromechanics, Basic lamina properties, Constituent materials and properties, Properties of typical composite materials

Unit 3. Elastic Behavior of Unidirectional Lamina [05 hrs]
Stress-strain relations, Relation between mathematical and engineering constants, transformation of stress, strain and elastic parameters

Unit 4. Strength of Unidirectional Lamina [05 hrs]
Micromechanics of failure; failure mechanisms, Macromechanical strength parameters, Macromechanical failure theories, Applicability of various failure theories

Unit 5. Elastic Behaviorof Laminate [08 hrs]
Basic assumptions, Strain-displacement relations, Stress-strain relation of layer within a laminate, Force and moment resultant, General load–deformation relations, Analysis of different types of laminates
Hygrothermal Effects:Hygrothermal effects on mechanical behavior, Hygrothermal stress-strain relations, Hygro-thermoelastic stress analysis of laminates, Residual stresses, Warpage

Unit 6. Stress and Failure Analysis of Laminates [05 hrs]
Types of failures, Stress analysis and safety factors for first ply failure of symmetric laminates, Micromechanics of progressive failure; Progressive and ultimate laminate failure, Design methodology for structural composite materials

Reference Books:

1. Isaac M. Daniels, OriIshai, “Engineering Mechaincs of Composite Materials”, Oxford University Press, 1994.
2. Bhagwan D. Agarwal, Lawrence J. Broutman, “Analysis and Performance of fiber composites”, John Wiley and Sons, Inc. 1990.
3. Mathews, F. L. and Rawlings, R. D., “Composite Materials: Engineering and Science”, CRC Press, Boca Raton, 2003.
4. MadhujitMukhopadhyay, “Mechanics of Composite Materials and Structures”, University Press, 2004.
5. Mazumdar S. K., “Composaite Manufacturing – Materials, Product and Processing Engineering”, CRC Press, Boca Raton, 2002.
6. Robert M. Jones, “Mechanics of Composite Materials”, Taylor and Francis, Inc., 1999.

Departmental Elective- III
ME (DE) XX001 Condition Monitoring

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks

End Sem. Exam: 60 marks

Course Outcomes:

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

- Understand the concept of condition-based maintenance of plant, machinery, equipment and structures, etc., in online and offline mode
- Understand the types of signals and sensors used to acquire vital health parameters of machineries to monitor changes that precede equipment failures.
- Analyze the fault in the machinery like gear boxes, bearings and shafts by using a variety of monitoring techniques.
- Interpret the data of rotating machinery and detect the onset of impending faults through vibration signature, acoustic emissions, thermography, oil-debris analysis, motor current signature analysis and /or several other NDT methods (Eddy Current Testing, Ultrasonic Testing, Radiography, etc.).
- Understand the techniques and analyze electronic component heat generation, leak detection as an aid to condition monitoring.
- Understand the techniques for the condition monitoring of the buildings, structures etc

Unit1: Introduction to Condition Monitoring and Principles of Maintenance [5 Hrs]

Machinery Condition Monitoring, Fault Diagnosis and Prognosis, Overview of Different Techniques of Condition Monitoring, Principles of Maintenance, Reactive, Preventive, Predictive Maintenance, Bath Tub Curve, Brief concept of Failure Modes Effects and Criticality Analysis (FMECA), RAMS standards (Reliability, Availability, Maintainability and Safety)

Unit 2: Digital Signal Processing and Instrumentation [6Hrs]

Introduction, Classification of Digital Signal Processing, Fundamentals of Fast Fourier Transform, Computer-Aided Data Acquisition, Signal Conditioning, Engine Vibration, Static and Dynamic Measurements, Frequency Response, Dynamic Range, Basic Measuring Equipment, Signal Amplifiers, RMS/Peak Meters, Oscilloscope, Signal Filter, etc., Laser-Based Measurements, Current Measurements, Chemical Composition Measurement, Data Recorders, etc.

Unit 3: Machinery Vibrations and Vibration Based CBM [10Hrs]

Introduction to Vibration, Forced Vibration Response, Characteristics of Vibrating Systems, Vibration of Continuous Systems, Experimental Modal Analysis, Mode Shapes and Operational Deflection Shapes, Rotodynamics, Unbalance Response and Critical Speed, Journal Bearings, Condition Monitoring in Large Rotor Systems

Misalignment Detection, Eccentricity Detection, Cracked Shaft, Bowed and Bent Shaft, Rub, Looseness, Bearing Defects, Gear Faults, etc, and case studies thereof.

Unit4: Noise Monitoring and Electrical Machinery Faults [7Hrs]

Introduction to Acoustical terminologies, Sound Pressure Level, A-Weighting, Sound Power Level, Sound Intensity Level, Octave Frequency Bands, Sound Fields, Near-Field Condition, Far-Field Condition, Anechoic/Reverberation Chamber, Noise Measurements, Acoustic Emission.
Faults and fault detection in Electric Motors, Fault Detection in Electro-Mechanical Systems by MCSA, Relation between Vibration and Motor Current, Fault Detection in a Submersible Pumps, etc.

Unit 5: Thermography and Wear Debris Analysis [7 Hrs]

Introduction to Thermography, Thermal Imaging Devices: Optical Pyrometer, Infrared Cameras, Industrial Applications of Thermography in Condition Monitoring
Electrical and Electronic Component Heat Generation, Leakage Detection,
Introduction to Wear Debris Analysis, Mechanisms of Wear, Detection of Wear Particles, Common Wear Materials, Oil Sampling Technique, Oil Analysis, Limits of Oil Analysis,
Other Methods: Eddy Current Testing, Ultrasonic Testing, Radiography, etc.

Unit 6: Cutting Tool Condition Monito [6Hrs]
Introduction, Tool Wear, Sensor Fusion in TCM, Sensors for Tool Condition Monitoring, Direct Tool Wear Measurements: Dimensional Deviation, Tool-Work Electric Resistance, Optical Sensors, Force/ Torque Sensor, Vibration Sensor, Surface Roughness, Acoustic Emission Sensor, Use of IoT, ML, AI and Data analytics in condition monitoring and fault diagnosis, etc.

Text books:

- Mohanty R A, Machinery, Condition Monitoring Principles and Practices, CRC Press, Taylor and Francis Group, (2015).
- P Girdhar, Machinery vibration analysis and predictive maintenance, Elsevier Newnes Publications. (2004)
- Collacott R.A., Mechanical fault diagnosis and condition monitoring, London: Chapman and Hall (1977).
- Rao, B. K. N., Handbook of condition monitoring, Elsevier advanced technology, Oxford. (1996)
- A Davis – Handbook of condition monitoring, London: Chapman and Hall. (1998)

Reference books:

- R G Eisenmann et-al – Machinery malfunction diagnosis and correction, Hewlett-Packard professional books. (1997)
- Robert Bond Randall, Vibration-based Condition Monitoring: Industrial, Aerospace and Automotive Applications (Google eBook) John Wiley & Sons. (2011)
- Ron Barron, Engineering condition monitoring: practice, methods and applications, Longman, (1996)
- E. D. Yardley, Condition Monitoring: Engineering the Practice, Wiley. (2002)

Departmental Elective- III
ME (DE) XX001 AI and ML for Mechanical Engineers

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Demonstrate fundamentals of AI&ML, apply feature extraction and selection techniques
- Apply machine learning algorithms for classification and regression problems
- Devise and develop a machine learning model using various steps
- Explain concepts of reinforced and deep learning
- Simulate machine learning model in mechanical engineering problems

Unit 1: Introduction
[07 Hrs.]
History of AI, Comparison of AI with Data Science, Need of AI in Mechanical Engineering, Machine Learning Basics: Reasoning, problem solving, Knowledge representation, Planning, Learning, Perception, Motion and manipulation. Approaches to AI: Cybernetics and brain simulation, Symbolic, Sub-symbolic, Statistical. Approaches to ML: Supervised learning, Unsupervised learning, Reinforcement learning

Unit 2: Development of ML Model [08 Hrs.]
Problem identification: Classification, Clustering, Regression, Ranking. Steps in ML modelling: Data Collection, Data pre-processing, Model Selection, Feature Extraction, Feature Selection, Model training (Training, Testing, K-fold Cross Validation), Model evaluation (understanding and interpretation of confusion matrix, Accuracy, Precision, Recall, True positive, false positive etc.), Hyper parameter Tuning, Predictions

Unit 4: Feature Extraction and Selection [07 Hrs.]
Feature extraction: Statistical features, Principal Component Analysis. Feature selection: Ranking, Decision tree - Entropy reduction & information gain, Exhaustive, best first, Greedy forward & backward

Unit 5: Classification & Regression [08 Hrs.]
Classification: Decision tree, Random forest, Naive Bayes, Support vector machine. Regression: Logistic Regression, Support Vector Regression. Regression trees: Decision tree, random forest, K-Means, K-Nearest Neighbour (KNN)

Unit 7: Deep & Reinforced Learning [07 Hrs.]
Introduction to Deep learning: Artificial neural networks, Deep neural networks, Convolutional neural network, Recurrent neural network, Long short term memory LSTM, Auto encoder (AE), Dip belief network, Generative adversarial network, Extreme learning machine, Deep residual network. Introduction to reinforced learning: Motivation, background, characteristics,

Algorithms for control learning: Criterion of optimality, Brute force, Value function, direct policy search, Model-based algorithms, Associative reinforcement learning, Deep reinforcement learning, Inverse reinforcement learning, Safe Reinforcement Learning, Partially Supervised Reinforcement Learning (PSRL)

Unit 8: Advanced & Recent Techniques [08 Hrs.]

Pitfalls of traditional ML models, Data expansion and augmentation, Adversarial Machine learning (AML), Domain generalization and adaptation, Transfer Learning (TL), Explainable AI (XAI), Digital Twin (DT), Multi-models, Multi-agent adaptation, Self-paced learning

Applications & Case Studies

- Health monitoring of rotating machine component (such as cutting tool, gearbox, hydraulic brake, pumps, turbines to name a few)
- Image-based classification of machine elements such as nuts, bolts, washers etc.
- Predicting the output and efficiency of thermal systems
- Predicting the material property & new materials discovery
- Wear state estimation of rolling element bearings using SVM
- Battery performance evaluation and management for a case of electric mobility
- Prediction of refrigerant two-phase pressure drop inside heat exchangers
- Predictive modeling of engine emissions
- Image driven machine learning methods for microstructure recognition
- Flow optimization using machine learning
- Intelligent ERP, ML-Driven Supply Chain
- Reinforcement learning for tool life extension on multi-sensor condition monitoring
- Sample augmentation for intelligent milling tool wear condition monitoring using numerical simulation and generative adversarial network
- An Explainable AI-Based fault diagnosis model for bearings
- Domain generalization & transfer learning in rotating machinery fault diagnostics DNN
- Big data oriented smart tool condition monitoring system
- Flow control via Reinforcement learning
- Kinematic Synthesis using Reinforcement Learning

Text Books:

- Tom M. Mitchell, “Machine Learning”, McGraw-Hill, 1997
- ShaiShalev-Shwartz and Shai Ben-David, “Understanding Machine Learning”, Cambridge University Press, 2017.
- MehryarMohri, AfshinRostamizadeh and AmeetTalwalkar, “Foundations of Machine Learning”, MIT Press, 2012
- P. Flach, “Machine Learning: The Art and Science of Algorithms that Make Sense of Data. First Edition”, Cambridge University Press, 2012.
- Kumar, Zindani, Davim, Artificial Intelligence in Mechanical and Industrial Engineering, CRC Press, 2021.

Papers:

- P. Domingos, “A Few Useful Things to Know about Machine Learning”, Communications of the ACM, vol. 55, no. 10, pp. 78 - 87, 2012.
- Steven L. Brunton, Bernd R. Noack, and PetrosKoumoutsakos, “Machine Learning for Fluid Mechanics”, Annual Review of Fluid Mechanics, vol. 52, pp. 477–508, 2020.

Departmental Elective- III
ME (DE) XX001 Sensors and Actuators in Robotics Technology

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Analyze sensory systems in robotics.
- Select the sensor for robotic application and design the system.
- Analyze actuators and configuring the parameters of Actuators

Syllabus Contents
Anatomy of Robotic system,
Basics of Sensors used in the Robotics Technology. Types of sensors: Pressure/contact. Resistive position. Infrared. Light. Position Sensors, optical encoders, proximity sensors, Range sensors Ultrasonic sensors, Touch and Slip sensors. sensors for motion and position, Force, torque and tactile sensors, Flow sensors, Temperature sensing devices,
Vision Sensors :- Vision System Devices, Image acquisition, Masking, Sampling and quantization, Image Processing Techniques , Noise reduction methods, Edge detection, Segmentation.
Advanced Sensor Technology - Smart sensors, MEMS based sensors, Innovations in sensor technology

Actuators and its selection while designing a robot system. Types of transmission systems, Electric Actuators - Direct current motor, Permanent magnet stepper motor, Servo Control DC motors, Linear and latching linear actuators, Rotatory actuators, Piezo electric actuators, Actuator parameters and characteristics, Stepper motors, Specifications and characteristics of Stepper motors Servomotors.

Pneumatic & Hydraulic actuators - Hydraulic and pneumatic power actuation devices Hydraulic Actuators, selection of linear actuating cylinders, Hydraulic Motors, Pneumatic actuators, design considerations and selection, pneumatic cylinders , pneumatic drive system, Linear & rotary actuators.
Advanced actuators – Piezoelectric actuators, elastomer actuators, soft actuators, shape memory alloy-based actuators, underactuated robotic hand

Reference Books:

- Mc Comb, G. Robot builder's bonanza. 5th ed. New York: McGraw-Hill, 2019. ISBN 9781260135015.
- Braünl, T. Embedded robotics: mobile robot design and applications with embedded systems. 3rd ed. Berlin ; Heidelberg: Springer, 2008. ISBN 9783540705338.

- Martin, F.G. Robotic explorations: a hands-on introduction to engineering. Upper Saddle River, N.J.: Prentice-Hall, 2001. ISBN 0130895687.
- D. Patranabis, Sensors and Transducers, PHI, 2nd Ed 2013
- Jon S. Wilson, Sensor Technology Handbook, Elsevier, 2005
- Andrzej M. Pawlak, Sensors and Actuators in mechatronics, Taylor & Francis Group, 2007
- S. R. Ruocco, Robot Sensors & Transducers, Springer, 2013
- Gerard C., M. Meijer, Smart Sensors System, Wiley, 2008

Departmental Elective- III
ME (DE) XX001 Project Management

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Manage the scope, cost, timing, and quality of the project, at all times focused on project success as defined by project stakeholders.
- Align the project to the organization's strategic plans and business justification throughout its lifecycle.
- Identify project goals, constraints, deliverables, performance criteria, control needs, and resource requirements in consultation with stakeholders.
- Implement project management knowledge, processes, lifecycle and the embodied concepts, tools and techniques in order to achieve project success.
- Utilize technology tools for communication, collaboration, information management, and decision support.
- Implement general business concepts, practices, and tools to facilitate project success.
- Apply appropriate legal and ethical standards

Unit I: Project Integration & Structures
Project and Importance of Project Management, Project Life Cycle, Role and Responsibilities of Project Manager, Project Integration Management. Project Management Structures, Right Project Management Structure, Organization Culture [6 hrs]

Unit II: Project Appraisal & Selection
Organization Strategy: Strategic Management Process, Need for Portfolio Management, Selection Criteria: Financial and Non-Financial [6 hrs]

Unit III: Project Planning, scheduling & Control
Defining the Project: Project Scope, Creating Work Breakdown Structure, Responsibility Matrix and Communication Plan.
Quality of Estimates and Guidelines, Methods for Estimating Project Times and Cost, Types of cost [6Hrs]

Unit IV: Managing Risk & People
Risk Management Process, Contingency Plans, Change Control Management, Managing Vs. Leading A Project Risk Management Process, Contingency Plans, Change Control Management, Managing Vs. Leading A Project
Managing Project Stakeholders, Influence as Exchange, Managing Project Teams: Team Development, Establishing Team identity, Managing Conflicts, Project Team Pitfalls [6 hrs]

Unit V: Project Planning, Scheduling & Control problems CPM & PERT
Developing a project plan and project network, AOA and AON diagram, CPM calculations, problem solving, PERT model, pert calculations, time scale network, problem solving , network scheduling with limited resources, heuristic programs, resource allocation & spar model, problem solving, precedence diagramming, decision networks, Pert network, problem solving, reducing project duration, project cost – duration graph, crashing of activities, project monitoring information system, developing status report, earned value analysis. [6 hrs]

Unit VI: Project Audit, Closure
Project audit, project closure, retrospectives [6 hrs]

Text Books:

- Cliford F. Grey, Erik W. Larson, Gautam V. Desai "Project Management The Managerial Process", McGraw Hill Education(India) Private Limited, New Delhi, Sixth Edition, 2014
- Jerome D Wiest& Ferdinand K Levy, "A Management Guide to PERT/ CPM with GERT/PDM/DCPM and other Networks", PHI Learning Private Limited, 2nd Edition 2009

Reference Books:

- Kerzner Harold," Project Management: A Systems Approach to Planning, Scheduling and Controlling", Wiley Student Edition 10th Ed.

Departmental Elective- IV
ME (DE) XX001 Design of Heat Exchangers

Teaching Scheme
Lectures : 3hrs / week
Tutorial: 1 hr/week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:
- Understand and explain different types of heat exchangers and its performance
- Design and analyze various heat exchangers using heat exchanger design standards and codes
- Appreciate and analyze the consequences of fouling on performance of heat exchangers and determine fouling resistance

- Carry out Thermal and Hydraulic design and analysis of heat exchangers for various real time problems including heat transfer coefficient enhancement and fouling effect
- Use simulation and optimization tools in heat exchanger design

Unit 1 **(6 hrs)**

Introduction to Heat Exchangers:
Types of heat exchangers and their applications, Flow arrangements and temperature distributions in transfer type of heat exchangers, Overall heat transfer coefficient;- Clean overall heat transfer coefficient, dirt factor dirt overall heat transfer coefficient, dirt factors for various process services. Basic design equation, Mean temperature difference Concept; LMTD for different flow arrangement, correction factor for LMTD for cross flow and multi –pass heat exchangers, Mean temperature difference method.

Unit 2 **(6 hrs)**

Shell and Tube Heat Exchangers:
Constructional features; Applications; Effectiveness-NTU method for heat exchanger design/ analysis, ϵ-NTU method, P-NTU method, Rating and sizing problem; Correlations for tube side pressure drop and heat transfer coefficients, Pressure drop; Kern's, and Bell Delaware's method, heat transfer coefficient correlations for shell side flow.

Unit 3 **(6 hrs)**

Fouling of heat exchanger**,** effects of fouling, categories of fouling, fundamental processes of fouling, determination of fouling resistance and consequences of fouling on performance of heat exchangers
By – Pass and Leakage Calculation Procedure for Shell and Tube Heat Exchanger

Unit 4 **(6 hrs)**

Double Pipe Heat Exchangers:
Thermal and Hydraulic design of inner tube, Thermal and hydraulic analysis of Annulus, Pressure drop analysis
Compact Heat Exchangers: Thermal and Hydraulic design of compact heat exchanger

Unit 5 **(6 hrs)**

Air-Cooled Heat Exchangers:
Air as coolant for industrial processes; custom-built units; fin-tube systems for air coolers; fin-tube bundles; thermal rating; tube side flow arrangements; cooling air supply by fans; cooling air supply in natural draft towers.

Unit 6 **(6 hrs)**

Mechanical Design of Heat Exchangers:
Design standards and codes, key terms in heat exchanger design, and thickness calculation for major components such as tube sheet, shell, tubes etc.

Text Books

- Ramesh K. Shah and Dusan P. Sekulic, "Fundamentals of Heat Exchanger Design" John Wiley & sons Inc., 2013

Reference Books

- D.C. Kern, "Process Heat Transfer", McGraw Hill, 1950
- SadikKakac and Hongton Liu, "Heat Exchangers: Selection, Rating and Thermal Design" CRC Press, 1998
- Geofrey F. Hewitt, "Hand Book of Heat Exchanger Design",Begell House, 1992.
- "T.E.M.A. Standard", New York, 1999
- KuppanThulukkanam, "Heat Exchanger Design Handbook", CRC Press, 2nd Edition, 2013

Departmental Elective- IV
ME (DE) XX001 Introduction to Nuclear Engineering

Teaching Scheme
Lectures : 2hrs / week
Tutorial: 1 hr/week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:

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

- The basic concepts and processes taking place inside a nuclear reactor, such as nuclear fission, neutron production, scattering, diffusion, slowing down and absorption.
- The student will be familiar with concepts of reactor criticality, the relationship between the dimension and fissile material concentration in a critical geometry.
- Time dependent (transient) behaviour of power reactor in non-steady state operation and the means to control the reactor.
- It will familiarize the student with concepts of heat removal from reactor core, reactor safety and radiation protection.
- Enhance problem solving skills, particularly solving differential equations in simple geometries.

Unit 1: (6hrs)

Basics of nuclear fission and power from fission

Radioactivity, nuclear reactions, cross sections, nuclear fission, power from fission, conversion and breeding

Unit 2: (9hrs)
Neutron transport and diffusion

Neutron transport equation, diffusion theory approximation, Fick's law, solutions to diffusion equation for point source, planar source, etc., energy loss in elastic collisions, neutron slowing down

Unit 3: **(9hrs)**
Multi-group, multi-region diffusion equation, concept of criticality

Solution of multi-group diffusion equations in one region and multi-region reactors, concept of criticality of thermal reactors

Unit 4: **(6hrs)**
Reactor kinetics and control

Derivation of point kinetics equations, inhour equation, solutions for simple cases of reactivity additions, fission product poison, reactivity coefficients

Unit 5: **(3hrs)**

Heat removal from reactor core

Solution of heat transfer equation in reactor core, temperature distribution, critical heat flux, etc.

Unit 6: **(3hrs)**
Reactor safety, radiation protection

Reactor safety philosophy, defence in depth, units of radioactivity exposure, radiation protection standards

Text Books

- Introduction to Nuclear Engineering (3rd Edition) by John R. Lamarsh, Anthony J. Barrata, Prentice Hall, (2001).
- Nuclear Reactor Analysis, by James J. Duderstadt and Lewis J. Hamilton, John Wiley (1976)

Reference Books

- Nuclear Reactor Engineering vol.1, Reactor Design Basics, CBS Publishers (2019).
- Introduction to Nuclear Reactor Theory, by John R. Lamarsh, Addison-Wesley, (1966).

Departmental Elective- IV
ME (DE) XX001 Nano Technology in Solar Engineering

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Describes the fundamentals of nanoparticles for the harnessing of solar energy

- Characterization techniques used for nano size particles
- Performance characterization of volumetric absorption-based solar collector
- Apply the concepts of nanotechnology on various applications

Unit 1: Fundamentals of solar energy [4]
Basic definitions related to solar energy, electromagnetic waves, solar angles, solar earth geometry, working mechanism of surface absorption-based solar collector (non-concentrating and concentrating), issues related to surface-absorption based solar collectors.

Unit 2: Fundamental of nanoparticles [8]
Concept of nanoparticles and nanofluid, materials of nanoparticles (metallic, core/shell, graphite and non-metallic), preparation methods of nanofluids (one step and two step methods), importance of nanosize, general issues of concern with nanoparticles, dispersion of nanoparticles in liquids.

Unit 3: Characterization of nanoparticles [8]
Transmission electron microscopy, X-ray diffraction, Infrared, Raman and other spectroscopies, zeta potential, UV-Vis spectroscopy, effect of shape of nanoparticles on the optical properties, forces exerted on nanoparticles.

Unit 4: Radiative properties [10]
Radiative transfer equation, derivation of the transfer equation, absorbing, emitting and non-scattering medium, scattering medium, out-scattering, in-scattering, phase function, radiative heat flux, single scattering albedo, Mie scattering, Rayleigh scattering, absorption coefficient and efficiency.

Unit 5: Dispersion theory in nanoparticles [6]
Interaction of electromagnetic radiation with matter, Lorentz model, Drude model, Interaction of electromagnetic radiation with nanofluid

Unit 6: Nanofluid based solar collector [7]
Working mechanism of nanofluid based solar collector, factors affecting the performance of solar collector, effect of mass flow rate, effect of volume fraction, effect of depth of nanofluid, effect of irradiation, applications of nanofluid based solar collectors.

Text books:

- Brewster, M. Q. Thermal Radiative Transfer and Properties. (Wiley, 1992).
- Das, S. K., Choi, S. U. S., Yu, W. & Pradeep, T. Nanofluids: Science and Technology. Wiley. Wiley (2007).
- Duffie, J. A. & Beckman, W. A. Solar Engineering of Thermal Processes. 4th ed. John Wiley & Sons. John Wiley & Sons (2013).
- Modest, M. F. Radiative Heat Transfer. Academic Process vol. 5 3896–3915 (2003).

Departmental Elective- IV
ME (DE) Fracture Mechanics

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Predict diferent modes of failure and diferentiate between brittle fracture and ductile fracture.
- Interpret the damage tolerance of a component with a crack by analyzing the problem by methods of energy release rate and stress intensity factor.
- Explore the test methods for determining critical energy release rate, critical stress intensity factor.
- Analyze stress and displacement fields at the tip of edge crack and embedded crack.
- Analyze variable amplitude fatigue in a component when a crack is present in it.
- Estimate crack propagation, and environment assisted cracking along with various crack detection techniques.

Unit I:

Energy Release Rate:
Kinds of failure, Brittle and ductile fracture, Modes of fracture failure, Damage tolerance, Grifth's Dilemma, Surface energy, Grifth's realization, Grifth's Analysis, Energy release rate, crack resistance, stable and unstable crack growth, R-curve for Brittle Cracks, Critical Energy Release Rate. [6 hrs]

Unit II:

Stress Intensity Factor:
Introduction, Stress and Displacement Fields in Isotropic Elastic Materials ,Stress intensity factor, Background for Mathematical Analysis, Westergaard's Approach, Application of the Principle of Superposition , Crack in a Plate of Finite Dimensions, edge cracks, embedded cracks , The Relation between GI and KI , critical stress intensity factor, Bending and Twisting of Cracked Plates. [6 hrs]

Unit III:

Crack tip plasticity:
Shape and size of plastic zone, efective crack length, efect of plate thickness, Crack tip opening displacement, Definition of the J-Integral, Path Independence, Stress-Strain Relation, Relationship between CTOD, KI and GI for Small Scale Yielding, Equivalence between CTOD and J. [6 hrs]

Unit IV :

Test Methods:

Introduction, Test methods for determining critical energy release rate, Test Methods to Determine JIc, Test Methods to Determine GIC and GIIC, Determination of Critical CTOD. [6 hrs]

Unit V:

Fatigue Failure and Environment-assisted fracture:
Introduction, Terminology, S-N Curve, Crack Initiation, Fatigue failure: Crack propagation, efect of an overload, crack closure, variable amplitude fatigue load, Micro mechanisms, Environment-assisted fracture, Environmentassisted Fatigue Failure, Major Factors Infuencing Environment-assisted Fracture, Test Methods. [6 hrs]

Unit VI:

Crack detection techniques:
Introduction, , various crack detection techniques, Examination through Human Senses, Liquid Penetration Inspection, Ultrasonic Testing, Radiographic Imaging, Magnetic Particle Inspection. [6 hrs]

Text Books:

- Kumar Prashant, "Elements of Fracture Mechanics", Tata McGraw-Hill,2009.
- Maiti S K, "Fracture Mechanics: Fundamentals and Applications",• Cambridge University Press, 2015.

Reference Books:

- Brook D, "Elementary engineering fracture mechanics', Springer, 2012.
- Liebowitz H.," Fracture" Volume I to VII, Academic Press Inc., Nov. 1972.
- Nadai A and Hemp W. S., "Theory of fow and fracture of solids", McGraw Hill Book Company, 1950.

Departmental Elective- IV
ME (DE) XX001 Mechanical Vibraions and Acoustics

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Model a given vibratory system as SDOF or MDOF system, with or without damping, and with base or force excitation as periodic or aperiodic.
- Evaluate natural frequencies and mode shapes of MDOF and continuous systems using modal analysis and computational methods such as Rayleigh-Ritz method and Holzer method.

- Explain various terminologies used in acoustics and acoustic wave transmission and estimate sound pressure level.
- Summarize the mechanism of hearing by human and principles of Psychoacoustics and noise control.

Unit 1: **(5hrs)**

Systems with one degree of freedom

Review of one degree of freedom, Energy method, Undamped, damped free and forced vibrations

Unit 2: **(6hrs)**

General forced response

Impulse response function, response to an arbitrary input, response to an arbitrary periodic input, response to random input, shock spectrum, stability.

Unit 3: **(6hrs)**

Systems with more than one degree of freedom system

Undamped free vibration: principal modes, semidefinite systems, steady state undamped forced vibrations, damped free vibrations, steady state forced vibrations with damping, influence coefficients, Generalised coordinates and coordinate coupling, principle coordinates, The langrage equation.

Unit 4: **(7hrs)**

Multi degree of freedom system matrix method

Undamped free vibration: principal modes, Normal coordinates, orthogonality of the principal modes of vibrations, systems with equal frequencies, Natural frequencies and principal modes by matrix iteration. Damped free vibrations, forced vibrations, Eigenvalues and natural frequencies, Modal analysis, modal analysis of the forced response. Design for vibration suppression, Vibration isolation, vibration absorbers

Unit 5: **(6hrs)**

Entropy

Plane Acoustic waves

Plane acoustic waves, derivation of plane wave equation relationship between acoustic pressure, particle displacement and velocity, velocity of plane acoustic waves, specific acoustic impedance, Sound power, sound intensity, sound pressure and sound intensity levels. Transmission Phenomena, transmission from one fluid medium to another, normal incidence reflection at the surface, of a solid,standing wave patterns.

Unit 6: **(8hrs)**

Psychoacoustics

Speech, Hearing and Noise, anatomy of the ear, mechanism of hearing, thresholds of the ear, loudness, pitch and timbre.

Text Books

- Francis S. Tse, Ivan E. Morse, Rolland “Mechanical Vibrations” 1963.

- Robert K. Vierck, “Vibration Analysis”1967.
- Inmann Daniel J. ,“Engineering Vibration”, 4th Edition, Pearson,2014.
- Thomson W.T., “Theory of vibrations with applications”, CBS Publishers, Delhi, 2008.
- Rao S.S., “Mechanical Vibrations”, Wiley Publishing Co., 2003.
- G. K. Grover, “Mechanical Vibrations” 1998.
- Kinsler Lawrence E. and Frey Austin R. “Fundamentals of Acoustics”, Wiley Eastern Ltd., 2000

Reference Books

- Timoshenko S, “Vibration problems in Engineering”, Wiley, 1990.
- Meirovitch Leonard, “Fundamentals of vibrations”, McGraw Hill International Edition, 2003.
- Rettinger Michael, “Acoustic Design and Noise Control”, Vol. I & II. , Chemical Publishing Co., New York, 1977.
- Shriniwasan P., “Mechanical Vibration Analysis”, Tata McGraw Hill,1982.

Departmental Elective- IV
ME (DE) XX001 Tribology

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Understand various theories of friction and wear and will be able to apply them to various practical situations.
- Understand the various surface measurement techniques and effect of surface texture on Tribologicalbehavior of a surface.
- Select materials and lubricants to suggest a tribological solution to a particular situation.
- Apply learning of the basics of hydrodynamic bearings.
- Use Raimondi and Boyd charts to design hydrodynamic journal bearing and slider shoe bearing.

Unit 1: **(4hrs)**
Basic concepts & areas of application of tribology

Unit 2: **(6hrs)**
Surface texture and measurement

Unit 3: **(8hrs)**
Theories of friction, Friction control

Unit 4: **(8hrs)**
Wear, types of wear, theories of wear, wear prevention

Unit 5: **(4hrs)**
Tribological properties of bearing materials and lubricants.

Unit 6: **(10 hrs)**
Lubrication Regimes, Hydrodynamic Journal Bearing, Slider shoe bearing, their applications

Text Books
- Principles in Tribology, Edited by J. Halling, 1975
- Bernard J. Hamrock, "Fundamentals of Fluid Film Lubrication", McGraw Hill Publication

Reference Books
- S.K. Basu, B. B. Ahuja, S. N. Sengupta , "Fundamentals of Tribology", EEE, PHI Pvt. Publications Ltd.
- A. Cameron, "Basic Lubrication Theory", Ellis Horwood Ltd, 1981.

Departmental Elective- IV
ME (DE) XX001 Advanced CAD/CAM

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:
- Develop an ability to create automated solid model using CAD Customization.
- understand CAD/CAM data exchange formats
- understand applications of CAD for computer aided Advanced Manufacturing Methods
- understand concept of Product Life Cycle Management (PLM)

Unit 1 **(6hrs)**

Introduction to Python Programming:
Data Types, Variables, Basic Input-Output Operations, Basic Operators. Boolean Values, Conditional Execution, Loops, Lists and List Processing.Writing functions in Python

Unit 2 **(6hrs)**

CAD Customization:
Need of Cad customization. OLE interfaces in CAD/CAM software; Use of General programming interfaces like VB, VBS, VC++, Open GL programming and System dependent programming interfaces like Visual LISP (AutoCAD), GRIP (Unigraphics), Pro-Programming (Pro/Engineer). Creating automated Solid modeling using Customization through API

Unit 3 **(6hrs)**

Data Exchange Formats:
Introduction to CAD/Cam data exchange formats. Direct and Indirect translators. Neutral file formats: Data Exchange format (DXF), Standard Triangular Languages (STL), Initial Graphics Exchange Specification (IGES), 3MF etc.

Unit 4 **(6hrs)**

Surface and Hyper patch Modeling:
Surface modeling methods, twist vector, algebraic and control point based hyper patch modeling techniques

Unit 5 **(7hrs)**

Additive Manufacturing Processes
Models and specifications, Process, working principle, Applications, Advantages and Disadvantages, Case studies of following: Solid-based Rapid Prototyping Systems: Fused Deposition Modeling (FDM), Laminated Object Manufacturing (LOM). Liquid based Rapid Prototyping Systems: Stereo lithography Apparatus (SLA). Powder Based Rapid Prototyping Systems: Selective laser sintering (SLS)

Unit 6 **(4hrs)**

Introduction to Product Life Cycle Management
Background, Overview, Need, Benefits, and Concept of Product Life Cycle, Components / Elements of PLM, Emergence of PLM, Significance of PLM, Customer Involvement, Threads of PLM- computer aided design (CAD), engineering data management (EDM), Product data management (PDM), computer integrated manufacturing (CIM, comparison of PLM to Engineering resource planning (ERP).

Text Books

- Solid Modelling, MarttiMantilya, Computer Science Press,2014
- Rapid prototyping: Principles and Applications, Chua C.K., Leong K.F. and LIM C.S, World Scientific publications , Third Edition, 2010
- Geometric modeling, Michael Morteanson,John Wiley publication
- Python Programming: An Introduction to Computer Science (3rd Edition), John M. Zelle

Reference Books

- Manuals of Professional CAD software such as Creo Parametric, NX, CATIA
- Additive Manufacturing Technologies, 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, 2013, Gibson, Ian, Rosen, David, Stucker, Brent.

Departmental Elective- IV
ME (DE) XX001 Manufactruring Philosophies

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Understand the various manufacturing philosophies for the excellence.
- Demonstration of professional and ethical responsibility in the chosen field.
- Realization of the significance of internal and external customer needs and wants.
- Understanding the role of leader in manufacturing and services

Unit I:

Introduction to World Class Manufacturing Manufacturing excellence and competition frame work of WCM- Hall's, Schonberger's Gunn's, Maskell.WCM and Indian manufacturing scenario. [6 hrs]

Unit II:

Total Quality Management Quality definition, Contribution of various quality guru, Customer satisfaction, Continuous improvement, Supplier partnership, performance measures of Quality. [6 hrs]

Unit III:

Tools and Techniques of TQM Matrix diagram, process decision program chart, Management tool- Force field analysis, afnity diagram, Pareto diagram, Histogram, Process fow diagram, why- why analysis, Cause and efect diagram, Benchmarking, Quality function deployment (QFD), ISO 9000, Malcom Baldrig Certificate, European Quality Award certification. [6 hrs]

Unit IV:

JIT Philosophy Just in time, seven waste, Basic element of JIT, KANBAN, PoKaYoKe, 5 S Theory, Implementation of JIT, Value engineering [6 hrs]

Unit V:

Total Productive Maintenance Introduction of maintenance, Learning and implementing TPM, Development Autonomous Group, Training pertaining to TPM, Calculation relation with availability of machine. [6 hrs]

Unit VI:

Business Process Reengineering Service Management, Introduction to concurrent engineering,Introduction to ERP and Supply chain management. [6 hrs]

Text books:

- Barsterfield, “Total Quality Management”, Pearson Publication, ISBN no 13-978-9332534452,Edition 4,2015.
- T.C. Cheng, S. Podolsky Springer “Science & Business Media”, 31-Jul1996 - Business & Economics.

Reference Books:

- B. S. Sahay, K. B. C. Saxena ,”WCM- A strategic Perspective”, Macmillan Publication, ISBN no 13-978-0333934746,2013.
- Mart and Telsang. S ,”Industrial Engineering and Production Management”, Chand Publication, ISBN no 13-978- 8121917735,2006.
- K.C. Arora. S.K ,”Total Quality Management”, Kataria and Sons Publication.
- Barsterfield ,”Total Quality Management”, Pearson Publication, ISBN no 13-978-8185749990,2010.

ME ( ) XX001 Major Project

Teaching Scheme
Practical: 4hrs / week

Examination Scheme
Term Work: 50 marks
Practical/Oral: 50 marks

Course Outcomes:
At the end of the course students will be able to:

The students in a group of not more than FOUR will work under the guidance of the faculty member on the project work undertaken by them. The completion of work, the submission of the report and assessment should be done at the end of Part I (1st Semester).

The project work may consist of,
1. A comprehensive and up-to-date survey of literature related to study of a phenomenon or product.
2. Design of any equipment and / or its fabrication and testing.
3. Critical Analysis of any design or process for optimizing the same.
4. Experimental verification of principles used in applications related to Production Engineering.
5. Software development for particular applications.
6. A combination of the above.

The objective is to prepare the students to examine any design or process or phenomenon from all angles, to encourage the process of independent thinking and working and to expose them to industry. The students may preferably select the project works from their opted elective subjects.

A synopsis of the selected project work (two to three pages typed on A4 size sheets) certified by the project guide, should be submitted before the month of June of year. The synopsis shall be a part of the final project report.

The students should submit the report in a prescribed format, at the end of 1 st semester. The report shall be comprehensive and presented in duplicate, typed on A4 size sheets and bound.

1. Term work will be assessed by the project guide along with one colleague appointed by the Head of Department.

2. The students will be examined orally by the external examiner and the project guide, as the internal examiner. Marks will be awarded on the basis of the work done and performance in the oral examination

Minor in Product Design and Optimization
ME (MI) XX002 Introduction to Optimization Techniques

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Formulate an optimization problem.
- Classify a problem.
- Apply the algorithms for design optimization.
- Test the optimality of an optimum solution

Unit I:

Introduction to optimization Basic principles, optimal problem formulation, classification of optimization problems, Diferences between classical and modern optimization techniques [4 hrs]

Unit II:

One dimensional minimization Optimality criteria, bracketing methods, direct search methods, gradient based search methods [8 hrs]

Unit III:

Multivariable Unconstrained Optimization Optimality criteria, direct search methods, gradient based search methods, applications [8 hrs]

Unit IV:

Constrained optimization KKT conditions, direct search methods, gradient based search methods, applications [8 hrs]

Unit V:

Linear programming Linear problem formulation, simplex method and duality in linear programming, sensitivity or post-optimality analysis, Karmarkar's method [4 hrs]

Unit VI:

Introduction to Genetic Algorithms Operators, method, applications like optimum design of spring, gear box, etc. [4 hrs]

Test Books:

- Kalyanmoy Deb, "Optimization for Engineering Design", Prentice Hall of India, New Delhi, 2016
- J. S. Arora, "Introduction to Optimum Design", McGraw Hill, New York, 2014

Reference Books:

- R.C. Johnson, "Optimum Design of Mechanical Elements" , Willey, New York, 2011
- L.C.W. Dixon, Birkhauser, "Non-Linear Optimization - Theory and Algorithms" , Boston, 2005

Honor in Hybrid and Electrical Vehicles
ME (DE) XX001 Hybrid and Electric Vehicle

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- Apply basic principles of hybrid and electric vehicle to design vehicle.
- Select appropriate cycle source of energy for the hybrid electric vehicle based on driving.
- Analyze the power and energy need of the various hybrid electric vehicle.
- Measure and estimate the energy consumption of the Hybrid Vehicles.
- Evaluate energy efficiency of the vehicle for its drive trains.

Unit 1 **(6 hrs)**

Introduction to Electric Vehicle:
History of Electric Vehicles, Development towards 21st Century, Types of Electric Vehicles in use today – Battery Electric Vehicle, Hybrid (ICE & others), Fuel Cell EV, Solar Powered Vehicles. Motion and Dynamic Equations of the Electric Vehicles: various forces acting on the Vehicle in static and dynamic conditions.

Unit 2 **(6 hrs)**

Induction to Hybrid Electric Vehicle:
Social and environmental importance of hybrid and electric vehicles, impact of modern drivetrains on energy supplies. Hybrid Electric drivetrains: Basic concept of hybrid traction, introduction to various hybrid Drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.

Unit 3 **(8hrs)**

Electric Drive Trains:
Basic concept of electric traction, introduction to various electric drive- train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis. Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency.

Unit 4 **(7hrs)**

Types of Storage Systems:
Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices. Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Calculation for the ratings.

Unit 5 **(7hrs)**

Modelling of Hybrid Electric Vehicle Range:

Driving Cycles, Types of Driving Cycles, Range modelling for Battery Electric Vehicle, Hybrid (ICE & others), Fuel Cell EV, Solar Powered Vehicles. Case study of 2-wheeler, 3-wheeler and 4-wheeled vehicles.

Unit 6 **(7hrs)**

Energy Management Strategies

Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy management strategies. Introduction to various charging techniques and schematic of charging stations.

Reference Books:

- James Larminie, J. Lowry, "Electric Vehicle Technology Explaned", John Wiley & Sons Ltd. 2003.
- M. Ehsani, Y. Gao, S. E. Gay and A. Emadi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design", CRC Press, 2004.
- S. Onori, L. Serrao and G. Rizzoni, "Hybrid Electric Vehicles: Energy Management Strategies",Springer, 2015.
- Iqbal Hussein, "Electric and Hybrid Vehicles: Design Fundamentals", CRC Press, 2003.

List of Open-Source Software/learning website:

- Online course: https://nptel.ac.in/course.html
- Ocw.mit.edu/courses
- https://www.eng.mcmaster.ca/mech/content/electric-and-hybrid-vehicles

Honor in Thermal Stream

ME (HO) XX005 Advanced Heat Transfer

Teaching Scheme
Lectures: 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- The students are expected to understand the subject of Heat Transfer in detail with capability to solve Industrial Problems.
- This will also create the base and interest among the students to carry out the Future Research

Unit I: Conduction- one and two dimensional

Unit II: Fins, conduction with heat source, unsteady state heat transfer

Unit III: Natural and forced convection, integral equation, analysis and analogies

Unit IV: Transpiration cooling, ablation heat transfer, boiling, condensation and two phase fow mass transfer, cooling, fuidized bed combustion

Unit V: Heat pipes, Radiation, shape factor, analogy, shields

Unit VI: Radiation of gases & vapours

References:

- J.P. Holman, "Heat Transfer", McGraw Hill Book Company, New York, 1990.
- Incropera and Dewitt, "Fundamentals of Heat and Mass Transfer", John Wiley and Sons, NewYork, 2000.
- Frank Kreith, "Principles of Heat Transfer", Harper and Row Publishers, New York, 1973.
- Donald Q. Kern "Process Heat Transfer", Tata McGraw Hill Publishing Company Ltd., New Delhi, 1975.
- Gupta and Prakash, "Engineering Heat Transfer", New Chand and Bros, Roorkee (U.P.) India, 1996.
- R.C. Sachdeva "Fundamentals of Engineering Heat and Mass Transfer", Wiley Eastern Ltd., India

Honor in Design Stream
ME (HO) XX006 Stress Analysis

Teaching Scheme
Lectures: 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Apply the tensorial approach of continuum mechanics for complex analysis and comprehend modern research material.
- Synthesis the basic field equations such as equilibrium equations, compatibility and constitutive relationship.
- Evaluate torsion, bending and two dimensional problems employing basic field equations, energy methods and plastic hinges.
- Estimate any complex analysis using proficient FEM software packages with framing correct boundary conditions.

Unit I:

Tensors:
Tensor, transformation of tensorial components, dot and cross product of vectors, eigenvalue problems, Gradient of a scalar, Gauss theorem. Stress Analysis; traction vector, Stress tensor, stress components at a point of a free surface, Principal stresses and principal directions, Mohr circle, theories of yielding. [6 hrs]

Unit II:

Deformation and strain:
Deformation gradient, polar decomposition theorem, Cauchy-Green tensor, Green strain tensor, small displacement strain tensor, engineering and tensorial strains, transformation of strain components in cylindrical coordinates. Compatibility relations in strain components and in stress components, conservation laws; conservation of linear momentum and angular momentum, equilibrium equations in Cartesian and cylindrical coordinates. [6 hrs]

Unit III:

Constitutive relations and Linear Elasticity:
Uniaxial stress tension test, true stress and true strain, strain energy density, generalized Hooks law, Isotropic materials, boundary conditions, principle of superposition, uniqueness, Saint-Venant's principle, Dislocations in crystalline materials, Bauschingerefect. [6 hrs]

Unit IV:

Two dimensional problems and Energy methods:
Plane stress, Plane strain, Biharmonic equation and Airy's stress function, Biharmonic equation in cylindrical coordinates, concentrated load on half space, Energy methods; strain energy and complimentary energy, principle of virtual work, principle of minimum potential energy, Rayleigh Ritz methods, Castiglione's theorems. [6 hrs]

Unit V:

Torsion:
Polar rotation, Prandlt stress approach, torsion of non-circular crosssections, Prandlt membrane analogy, torsion of thin plates and thin wall tubes. [6 hrs]

Unit VI:

Bending and Shearing:
Short beam, bending of asymmetrical sections, shear stress on a thin wall open section [6 hrs]

Text Books:

- Arbindkumar Singh, "Mechanics of solids", Prentice Hall of India Pvt. Ltd, New Delhi, 2007.
- Srinath L.S, "Advanced Mechanics of Solids", Tata McGraw Hill Education, New Delhi, 2009.

Reference Books:

- Sadd Martin H., “Elasticity: Theory, Applications and Numerics”, Elsevier, 2014.
- Boresi A.P. and K. P. Chong, “Elasticity in Engineering Mechanics”, Second Edition, John Wiley & Sons, 2000.
- Budynas R. G., “Advance strength and Applied Stress Analysis”, Second Edition, McGraw Hill, 1999.
- Dally J. W. and Riley W.F., “Experimental Stress Analysis”, McGraw Hill International, 2005.

Minor in Product Design and Optimization

ME (MI) XX005 Introduction to CAD/CAM

Teaching Scheme
Lectures: 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Recall the fundamentals of CAD/CAM
- Compare and Represent 2-D and 3-D entities
- Apply transform techniques on 2-D and 3-D entities
- Examine CNC program for production of components
- Express the principles and methods of Rapid Prototyping

Unit I:

Fundamentals of CAD/CAM Product cycle and scope of CAD/CAM/CIM in product cycle, Features of CAD/CAM Hardware and software. [3hrs]

Unit II:

Representation of Curves and surfaces Introduction to Analytic Curves, Synthetic Curves: Hermite Cubic Spline, Bezier Curve, B-Spline curve. Surface Representation: Synthetic Surfaces [5 hrs]

Unit III:

Solid Modeling 2D Vs 3D modeling, Comparison of Wireframe, surface and solid modeling techniques, Geometry Vs Topology, Requirements of Solid Modeling, Constructive Solid Geometry (CSG), Boundary Representation (B-rep), etc. [5 hrs]

Unit IV:

Geometric Transformation 2D geometric transformations, Homogeneous co-ordinate representation, Composite transformations, 3D transformations, geometric mapping [3 hrs]

Unit V:

Computer Numerical Control and Part Programming Introduction to NC/CNC/DNC machines, Classification of NC systems, Axis nomenclature, Interpolation, features of CNC controllers, Types of CNC machines, Construction features of CNC machines, Manual Part Programming, , NC word format, Details of G and M codes, Canned cycles, subroutines and Do loops, Tool radius and length compensations [7 hrs]

Unit VI:

Rapid Prototyping and Manufacturing Introduction to Rapid Prototyping, rapid tooling and rapid manufacturing. Process of rapid prototyping. Diferent techniques of Rapid prototyping and their applications. [3 hrs]

Text Books:

- Ibrahim Zeid ,CAD/CAM Theory and Practice, , Tata McGraw-Hill
- Publishing Company Ltd., New Delhi,2012 Dacid F. Rogers, J Alan Adams, Mathematical Elements for Computer
- Graphics, McGraw-Hill publishing Company Ltd.,2001 Chougule N.K., CAD/CAM/CAE, Scitech Publications Ltd, 2017

Reference Books:

- M.E. Mortenson, Geometric Modelling , Wiley, 2016
- Bedworth, Wolfe & Henderson Computer Aided Design & Manufacturing , McGraw Hill, 2003

Honor in Hybrid and Electric Vehicle

ME (HO) XX005 Automotive Transmission and Control

Teaching Scheme
Lectures: 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Understand basics of automotive transmission.
- Understand shift mechanism and clutch control.
- Get familiar with function development of transmission control systems.
- Understand various types of transmission such as AT, AMT, MT.

Unit 1

Introduction to Automotive transmission:
Working principle and construction of Automotive Transmissions, Types of automotive transmissions, Manual Transmissions, CVT, DCT

Unit 2

Transmission System Design:
Transmission requirement in a vehicle, gear ratios, Selecting the Ratios, Overall Gear Ratio, Selecting the Largest Powertrain Ratio, Selecting the Smallest Powertrain Ratio, Final Ratio. Selecting the Intermediate Gears, matching of powertrain.

Unit 3

Automated Manual Transmission (AMT) & Automatic Transmission (AT):
Introduction to Automated manual transmissions, working and construction, different configurations of AMT, actuators in AMT, Automatic transmission, working and construction, shifting strategies, features of AMT & AT, comparison with MT

Unit 4

Transmission Control System:
Introduction to Transmission Control System, Transmission control unit, Function Development of Transmission Control System, Sensors and Actuators

Unit 5

EV transmissions:
Requirements of transmission in electric vehicle, features of EV transmission, types, configurations, performance parameters , design consideration for EV transmission,

Unit 6

Hybrid Vehicle Transmission:
HEV requirements of torque, different types of configurations in HEV, performance of hybrid transmissions, design parameters of HEV transmission systems.

References:

- Vehicle Powertrain Systems, BehroozMashadi , David Crolla, John Wiley & Sons, Ltd, 2012

- Automotive Engineering Powertrain, Chassis System and Vehicle Body, David Crolla, Butterworth-Heinemann, 2009
- Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives 1st Edition, Chris Mi , M. AbulMasrur , David Wenzhong Gao , Wiley; 2011
- Electric Vehicle Technology Explained 1st Edition, James Larminie, John Lowry , Wiley; 2003.

Honor in Thermal Stream

ME (HO) XX005 Modeling of IC Engine

Teaching Scheme
Lectures: 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):

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

- Develop and calibrate engine models
- Develop and calibrate single and double zone combustion models
- Analyse zero dimensional Models

Unit I:

Fundamentals:

Governing equations, Equilibrium charts of combustion chemistry, chemical reaction rates, and approaches of modeling, model building and integration methods, gas exchange through valves, exhaust gas recirculation, valve lift curves. [8 hrs]

Unit II:

Thermodynamic Combustion Models of CI Engines:

Single zone models, premixed and difusive combustion models, combustion heat release using wiebe function, wall heat transfer correlations, ignition delay, internal energy estimations, two zone model, application of heat release analysis. [10 hrs]

Unit III:

Fuel spraybehavior:

Fuel injection, injection characteristics, spray structure, fuel atomization, droplet turbulence interactions, droplet impingement on walls. [8hrs]

Unit IV:

Mathematical models of SI Engines:

Simulation of Otto cycle at full throttle, part throttle and supercharged conditions. Progressive combustion, Autoignitionmodeling, single zone models, mass burning rate estimation, SI Engine with stratified charge. Friction in pumping, piston assembly, bearings and valve train etc. friction estimation for warm and warm up engines. [10hrs]

References:

- Haywood, "I.C. Engines", McGraw Hill,2017.
- Ramos J, "Internal Combustion Engine Modeling". CRC Press,1989
- C. D. Rakopoulos and E. G. Giakoumis, Evangelos G. "Diesel Engine Transient Operations, Springer ,2009.
- V. Ganeshan, "Computer simulation of spark engine processes", Universities Press, 1996.
- P.A. Lakshminarayanan and Y. V. Aghav, " Modelling Diesel Combustion" Springer, 2010
- Bernard Challen and RodicaBaranescu, "Diesel Engine Reference Book" Butterworth-Heinemann, 1999.

Honor in Design Stream
ME (HO) XX006 Advanced Vibration and Acoustics

Teaching Scheme
Lectures: 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End– Sem. Exam: 60 marks

Course Outcomes (COs):
At the end of the course students will be able to:

Unit I

Transient Vibrations, Response of a single degree of freedom system to step and any arbitrary excitation, convolution (Duhamel's) integral, impulse response function. [6 hrs]

Unit II

Multi degree of freedom systems, Free, damped and forced vibrations of two degree of freedom systems, Eigen values and Eigen vectors, normal modes and their properties, mode summation method, use of Lagrange's equations to derive the equations of motion. [6 hrs]

Unit III

Continuous Systems, Vibrations of strings, bars, shafts and beams, discretised models of continuous systems and their solutions using Rayleigh – Ritz method, Mode summation method. [6 hrs]

Unit IV

Vibration Control, Methods of vibration control, Non-linear vibrations, Systems with non-linear elastic properties, principle of superposition, Numerical and computer methods in vibrations: Rayleigh, Rayleigh-Ritz and Dunkerley's methods, matrix iteration method for eigen-value calculations, Holzer's method. [6 hrs]

Unit V

Plane and Spherical acoustic waves, Transmission Phenomena, transmission from one fuid medium to another, normal incidence, refection at the surface of a solid, standing wave patterns, transmission through three media, Resonators and filters, Absorption of sound waves in fuids : Phase log between pressure and condensation, viscous absorption of plane waves, heat conduction as a source of acoustic attenuation. [6 hrs]

Unit VI

Speech, Hearing and Noise, The voice mechanism, acoustic power output of a speech, anatomy of the ear, mechanism of hearing, thresholds of the ear, loudness, pitch and timbre, beats, aural harmonics and combination tones, masking by pure tones, masking by noise. [6 hrs]

References:

- Thomson W.T., "Theory of Vibrations with applications", George Allen and Unwh Ltd. London, 1981.
- S.S. Rao, Addison, "Mechanical Vibrations", Wesley Publishing Co., 1990.
- Leonard Meirovitch, "Fundamentals of vibrations", McGraw Hill International Edition.
- S. Timoshenko, "Vibration problems in Engineering", Wiley, 1974.
- Lawrence E. Kinsler and Austin R.Frey, "Fundamentals of acoustics", Wiley Eastern Ltd., 1987.
- Michael Rettinger, "Acoustic Design and Noise Control", Vol. I & II. , Chemical Publishing Co., New York, 1977.

Interdisciplinary Open Course (IOC)
ME (DE) XX001 Air Conditioning

Teaching Scheme
Lectures : 3hrs / week

Examination Scheme
Internal Test 1: 20 marks
Internal Test 2: 20 marks
End Sem. Exam: 60 marks

Course Outcomes:
At the end of the course students will be able to:

- To understand the concepts of Psychometry.
- To know working of various Air-conditioning systems.
- To estimate cooling load for various applications.

- To design the A.C. systems.
- To design duct system for a central A.C.systems.

Unit 1 **[10hrs]**

Psychrometry:
Introduction, Applications of Air conditioning, Psychrometry, Psychrometry chart, Typical Air-conditioning process, Adiabatic cooling, Sensible heating, Cooling with humidification Process, Heating and Humidification, Adiabatic mixing of air streams, Air washer, Chemical dehumidification (Numerical Treatment).

Unit 2 **[6hrs]**

Air-conditioning systems:
Introduction ,Classification of Air-conditioning systems, Unitary systems, Central Classification of Air-conditioning systems, Reheat system, Multizone system, Dual Duct system, Variable Air Volume system (VAV) system, All – air and water systems, Unitary Vs Central systems.

Unit 3 **[8hrs]**

Cooling Load Estimation:
Introduction, Comfort, Human comfort chart, Outside Design conditions, Sources of heat load ,conduction through Exterior structures, Heat gain through glass , infiltration, ventilation, outside air load , heat load from people, Lightning, heat gain from equipment, System heat gain room cooling loads, cooling coil load.

Unit 4 **[6hrs]**

Designing the Air-Conditioning Systems:
Psychometric analysis of Air-conditioning systems, Summerairconditing systems provided with Ventilation air, Room sensible heat factor (RSHF).

Unit 5 **[5hrs]**

Air-conditioning Components:
Cooling coil, Heating coils, Air cleaning devices, Humidifiers, Fan, Air distribution systems.

Unit 6 **[5hrs]**

Duct Design:
Introduction , classification ,Duct materials, Continuity equation , Energy equation for pipe flow, total static velocity pressure , Static region , Pressure loss in duct Rectangular sections equivalent to circular duct. Dynamic losses in duct, Methods of duct design, Duct arrangement systems.

Text Books

- R.J.Dossat, “Principles of Refrigeration”, Pearson Education Asia, 2001
- C.P.Arora, “Refrigeration and Air-conditioning”, Tata McGraw-Hill, 2000
- Stoecker& Jones, “Refrigeration and Air-conditioning”, McGraw Hill Book Company, New

York, 1982.
- S.N. Sapali “Refrigeration and Air-conditioning”, PHI, 2016

Reference Books

- J.L.Threlkeld, “Thermal Environmental Engineering”, Prentice Hall, 1970.
- W.F.Stoecker, “Industrial Refrigeration Handbook”, McGraw-Hill, 1998.
- P.C.Koelet, “Industrial Refrigeration: Principles, Design and Applications”, Macmillan, 1992
- ASHRAE HANDBOOKS (i) Fundamentals of Refrigeration.
- “Handbook of air-conditioning system design”, Carrier Incorporation, McGraw Hill Book Co.,U.S.A, 1965.
- Jones W.P., “Air Conditioning Engineering”, Edward Arnold Publishers Ltd., London, 1984.
- Hainer R.W., “Control Systems for Heating, Ventilation and Air-Conditioning”, Van Nostrand