INSTITUTE OF ENGINNERING AND TECHNOLOGY LUCKNOW

(An Autonomous Constituent Institute of Dr. A.P.J. Abdul Kalam Technical University, Lucknow)

Scheme &Syllabus

For

B. Tech. Third Year

(Mechanical Engineering)

[Effective from the Session: 2024-25]

B.Tech. Mechanical Engineering

Third Year (Semester-V)

Sl. No.	Subject Code	Subject Name	Type of Course	Periods			Evaluation Scheme				End Semester		Total	Credit
				L	T	P	CT	TA	Total	PS	TE	PE		
1	IME501	Heat and Mass Transfer	PC	3	1	0	20	10	30		70		100	4
2	IME502	Machine Design	PC	3	1	0	20	10	30		70		100	4
3	IME503	Unconventional Manufacturing Processes	PC	3	1	0	20	10	30		70		100	4
4	IME051-054	Program Elective Course-I	PEC	3	0	0	20	10	30		70		100	3
5	IME055-058	Program Elective Course-II	PEC	3	0	0	20	10	30		70		100	3
6	IME551	Heat Transfer Lab	PL	0	0	2				50		50	100	1
7	IME552	Machine Design Lab	PL	0	0	2				50		50	100	1
8	IME553	I.C. Engine Lab	PL	0	0	2				50		50	100	1
9	IME554	Mini Project or Internship Assessment*	PL	0	0	2				100			100	1
		Total		15									**900**	**22**

*The Mini Project or internship (4 weeks) conducted during summer break after IV semester will be assessed during Vth semester.

Abbreviation Used:

PC: Program Course
PL: Program Lab
PEC: Program Elective Course
VA: Value Added Course

B.Tech. Mechanical Engineering

Third Year (Semester-VI)

Sl. No.	Subject Code	Subject Name	Type of Course	Periods			Evaluation Scheme				End Semester		Total	Credit
				L	T	P	CT	TA	Total	PS	TE	PE		
1	IME601	Refrigeration and Air Conditioning	PC	3	1	0	20	10	30		70		100	4
2	IME602	Theory of Machine	PC	3	1	0	20	10	30		70		100	4
3	IME603	Industrial Engineering	PC	3	1	0	20	10	30		70		100	4
4	IME061-064	Program Elective Course-III	PEC	3	0	0	20	10	30		70		100	3
5	IOE060-069	Open Elective-I	OEC	3	0	0	20	10	30		70		100	3
6	IME651	Refrigeration and Air Conditioning Lab	PL	0	0	2				50		50	100	1
7	IME652	Theory of Machine Lab	PL	0	0	2				50		50	100	1
8	IME653	Fluid Machinery Lab	PL	0	0	2				50		50	100	1
9	IME654	Seminar/Startup	PL	0	0	2				100			100	1
		Total		15									**900**	**22**

Abbreviation Used:

PC: Program Course
PL: Program Lab
PEC: Program Elective Course
OEC: Open Elective Course
VA: Value Added Course

Program Elective Courses

Program Elective Course -I
IME 051: I.C. Engine
IME 052: Production & Operations Management
IME 053: Mechanical Vibration
IME 054: Tribology

Program Elective Course -II
IME 055: Mechatronics
IME 056: Artificial Intelligence
IME 057: Non-destructive Testing
IME 058: Product Design and Development

Program Elective Course -III
IME 061: Fluid Machinery
IME 062: Gas Dynamics and Jet Propulsion
IME 063: Computer Integrated Manufacturing
IME 064: Finite Element Methods

Open Elective Course

Open Elective Course -I
IOE 066: Product Innovation & Entrepreneurship

Syllabus

IME 501	Heat and Mass Transfer	3L:1T:0P	4 Credits

Unit	Topics	No. of Hours
I	**Introduction to Heat Transfer:** Introduction of thermodynamics and Heat Transfer, Modes of Heat Transfer: Conduction, Convection and Radiation, Effect of temperature on thermal conductivity of different types of materials, Introduction to combined heat transfer mechanism, General differential heat conduction equation in the rectangular, cylindrical and spherical coordinate systems, Initial and system boundary conditions. **Steady State one-dimensional Heat conduction:** Simple and Composite Systems in rectangular, cylindrical and spherical coordinates with and without energy generation, Concept of thermal resistance, Analogy between heat and electricity flow, Thermal contact resistance and over-all heat transfer coefficient, Critical radius of insulation for cylindrical, and spherical bodies	9
II	**Extended Surface Heat Transfer (Fins):** Heat transfer through extended surfaces and its classification, Fins of uniform cross-sectional area, Performance of fins – efficiency and effectiveness, proper length of the fin, Types of fins: Pin fin, rectangular, Parabolic and annular fin, Error in measurement of temperature of thermometer wells. **Transient Conduction:** Transient heat conduction, Lumped capacitance method, Time constant, Unsteady state heat conduction in one dimension only, Heisler charts and their applications. Numerical methods in conduction Steady state one dimensional and two-dimensional problems One dimensional transient problems – Explicit and Implicit.	8
III	**Forced Convection:** Basic concepts: Hydrodynamic boundary layer, Thermal boundary layer, Approximate integral boundary layer analysis, Analogy between momentum and heat transfer in turbulent flow over a flat surface, Mixed boundary layer, Flow over a flat plate, Flow across a single cylinder and a sphere, Flow inside ducts, Thermal entrance region, Empirical heat transfer relations, Relation between fluid friction and heat transfer, Liquid metal heat transfer. **Natural Convection:** Physical mechanism of natural convection, Buoyant force, Empirical heat transfer relations for natural convection over vertical planes and cylinders, horizontal plates, cylinders and sphere, combined free and forced convection, Effect of turbulence.	9
IV	**Thermal Radiation:** Basic concepts of radiation, Radiation properties of surfaces, Black body radiation Planck's law, Wein's displacement law, Stefan-Boltzmann law, Kirchhoff's law, Gray body, Shape factor, Black-body radiation, Radiation exchange between diffuse non-black bodies in an enclosure, Radiation shields, Radiation combined with conduction and convection; Absorption and emission in gaseous medium; Solar radiation; Greenhouse effect, Radiation network analysis.	8
V	**Heat Exchanger:** Different types of heat exchangers: parallel flow, counter flow, cross flow, shell and tube, and compact heat exchanger, Fouling factors, Overall heat transfer coefficient, Logarithmic mean temperature difference (LMTD) method, Effectiveness-number of transfer unit (NTU) method.	8

	Condensation and Boiling: Introduction of condensation phenomena, Heat transfer relations for laminar film condensation on vertical surfaces and on outside& inside of a horizontal tube, Effect of non-condensable gases, Drop wise condensation, Heat pipes, Boiling modes, pool boiling, Hysteresis in boiling curve, Forced convection boiling. **Introduction to Mass Transfer:** Introduction of Fick's law of diffusion, Steady state equimolar counter diffusion, Steady state diffusion through a stagnant gas film, Heat and Mass Transfer Analogy -Convective Mass Transfer Correlations	

Course Outcomes:

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

COs	Statements
CO1	Understand and apply the fundamental concepts of thermodynamics and heat transfer and different modes of heat transfer.
CO2	Apply the concept of steady and transient heat conduction and thermal behaviour of fins.
CO3	Apply the concept of forced and free convection.
CO4	Apply the concept of radiation for black and non-black bodies.
CO5	Conduct thermal analysis of heat exchangers and understand the basics concept of condensation, boiling and mass transfer.

Reference Books:

1. Fundamentals of Heat and Mass Transfer, by Incroperra F.P. & Dewitt, John Wiley and Sons
2. Heat and Mass Transfer by Yunus A. Cengel, McGraw-Hill
3. Heat Transfer by J.P. Holman, McGraw-Hill
4.Heat and Mass Transfer, by PK Nag, McGraw-Hill Education - Europe
5. Heat and Mass Transfer by Rudramoorthy and Mayilsamy, Pearson Education
6. Heat Transfer by Ghoshdastidar, Oxford University Press
7. A text book on Heat Transfer, by Sukhatme, University Press.
8. Heat Transfer by Venkateshan, Ane Books Pvt Ltd
9. Schaum's outline of Heat Transfer by Pitts & Sisson McGraw-Hill
10. Heat and Mass Transfer by R Yadav, Central Publishing House

IME 502	Machine Design	3L:1T:0P	4 Credit

Unit	Topics	No. of Hours
I	**Introduction:** Definition, Design requirements of machine elements, Design procedure, Standards in design, Standards designation of carbon & alloy steels, Selection of preferred sizes, Selection of materials for static and fatigue loads, Design against Static Load **Design against Fluctuating Loads:** Cyclic stresses, Fatigue and endurance limit, Stress concentration factor, Stress concentration factor for various machine parts, Design for finite & infinite life, Soderberg, Goodman, Gerber criteria	8
II	**Riveted Joints:** Riveting methods, materials, Types of rivet heads, Types of riveted joints, Caulking and Fullering, Failure of riveted joint, Efficiency of riveted joint, Design of boiler joints, Eccentric loaded riveted joint **Welded Joints:** Stress relieving of welded joints, Butt Joints, Fillet Joints, Strength of Butt Welds, Strength of parallel fillet welds, Strength of transverse fillet welds **Shafts:** Cause of failure in shafts, Materials for shaft, Stresses in shafts, Design of shafts subjected to twisting moment, bending moment and combined twisting and bending moments, Shafts subjected to fatigue loads, Design for rigidity, Keys, Types of keys, Selection of square and flat keys, Strength of sunk key	8
III	**Spur Gears:** Tooth forms, System of gear teeth, contact ratio, Standard proportions of gear systems, Interference in involute gears, Backlash, Selection of gear materials, Gear manufacturing methods, Design considerations, Beam strength of gear tooth, Dynamic tooth load, Wear strength of gear tooth, Failure of gear tooth, Design of spur gears, AGMA and Indian standards. **Helical Gears:** Terminology, Proportions for helical gears, Force components on a tooth of helical gear, Virtual number of teeth, Beam strength and wear strength of helical gears, Dynamic load on helical gears, Design of helical gears.	9
IV	**Sliding Contact Bearing:** Types, Selection of bearing, Plain journal bearing, Hydrodynamic lubrication, Properties and materials, Lubricants and lubrication, Hydrodynamic journal bearing, Heat generation, Design of journal bearing. **Rolling Contact Bearing:** Advantages and disadvantages, Types of ball bearing, Thrust ball bearing, Types of roller bearing, Selection of radial ball bearing, Bearing life, Selection of roller bearings, Dynamic equivalent load for roller contact bearing under constant and variable loading, Reliability of Bearing.	9
V	**IC Engine Parts:** Selection of type of IC engine, General design considerations, Design of Cylinder and cylinder head; Design of piston, piston ring and gudgeon pin; **Friction Clutches** Clutches, Difference between coupling and clutch, Single plate friction clutch, Torque transmitting capacity, Multi-Disk Clutches, Friction Material	8

Note: Design data book is allowed in the examination

Course Outcomes:

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

COs	Statements

CO1	Understand the basic concepts of Solid Mechanics to understand the subject.
CO2	Classify various machine elements based on their functions and applications.
CO3	Apply the principles of solid mechanics to machine elements subjected to static and fluctuating loads.
CO4	Analyze forces, bending moments, twisting moments and failure causes in various machine elements to be designed.
CO5	Design the machine elements to meet the required specification.

Text Books:

1. Design of Machine Elements-V.B. Bhandari, McGraw Hill Co.
2. Design of Machine Elements, Sharma and Purohit, PHI.

Reference Books:

1. Mechanical Engineering Design, 9e – Joseph E. Shigely, McGraw Hill Education.
2. Machine Design-Maleev and Hartman, CBS Publishers.
3. Design of Machine Design-M.F. Spott, Pearson Education.
4. Elements of Machine Component Design, Juvinal&Marshek, John Wiley & Sons.
5. Machine design, Robert L. Norton, Pearson Education
6. Theory & Problem of Machine Design (Schaum's Outline Series) Hall, Holowenko, Laughlin, Tata McGraw Hill Co.
7. Machine Design-Sharma and Agrawal, S.K. Kataria& Sons.
8. Machine Design, U C Jindal, Pearson Education

IME 503	**Unconventional Manufacturing Processes**	**3L:1T:0P**	**4 Credit**

Unit	Topics	No. of Hours
I	**Unconventional Machining Processes:** Abrasive Jet Machining, Water Jet Machining; Ultrasonic Machining; Electrical Discharge Machining, Wire EDM; Electro Chemical Machining; Laser Beam Machining, Plasma Arc Machining and Electron Beam Machining; Micro and nano manufacturing.	9
II	**Powder metallurgy –** Introduction, Production of Metal Powders, powder characteristics, Compaction of Metal Powders, Sintering, Secondary and Finishing Operations, Design Considerations, Economics of Powder Metallurgy **Advances in Welding Processes:** Laser beam welding, Electron beam welding, Ultrasonic welding, Explosive welding, Friction Stir Welding, Underwater welding, Narrow Gap, Tandem (Twin / Multi Wire) Welding, A-TIG, Hybrid Welding processes, magnetically impelled arc butt (MIAB) welding, welding automation and robotic applications.	9
III	Rapid Prototyping: Need for additive manufacturing (AM)/3D Printing (3DP)/Rapid Prototyping (RP), Background, Types of AM materials, Liquid, solid and powder-based AM technologies, Steps of AM, Benefits of AM: manufacturing, medical and socio- cultural sectors.	8
IV	Computer Integrated Manufacturing: Meaning of CIM, Introduction to CIM, Role of Management in CIM, Expert system, Introduction to CAM, Scope in Engineering, NC controllers, types of CNC, the evolution of controllers, components of CNC, CNC tooling, CNC Programming. Part programming fundamentals, Manual part programming methods, Various G & M codes, Absolute and incremental system	8
V	**Measurement Principles:** Calibration principles; Linear and angular measurements; Comparators; Gauge design; Dimensional metrology – Vernier, micrometers, LVDT, surface profiler, CMM, 3D scanning; Surface metrology – optical microscopes, Laser scanning microscopes **Limits, Fits & Tolerance:** Definitions; Tolerance zone and grades, Hole and shaft system, Geometric tolerances, Tylor's principle of gauging, Design of tolerances for various applications; Tolerance analysis in manufacturing and assembly; Role of metrology in Design of Manufacturing.	8

Course Outcomes:

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

COs	Statements
CO1	Understand and apply the various non-conventional processes in manufacturing to develop a product
CO2	Understand the basics of Powder metallurgy process
CO3	Access the importance of rapid prototyping in manufacturing and apply knowledge to select appropriate welding process based on the type of industrial application.
CO4	To enable students to prepare CNC programs for various types of jobs on CNC milling machine
CO5	Apply the concept of limit, fits and tolerances in different applications

Reference Books:

1. M. P. Groover, Fundamentals of Modern Manufacturing: Materials, Processes, and Systems,

Third edition. Wiley India Private Limited, 2009
2. S. Kalpakjian, Manufacturing Processes for Engineering Materials, Fifth edition. Pearson Education, 2009
3. Geoffrey Boothroyd and Winston A. Knight, Fundamentals of Metal Machining and Machine Tools, 3 edition, CRC Press, 2005
4. Amitabha Ghosh and Mallick A. K., Manufacturing Science. Affiliated East-West Press Pvt. Ltd. 2010.
5. John A. Schey, Introduction to Manufacturing Processes, 3 edition, McGraw Hill Education, 2012
6. Manufacturing Technology- foundry, forming & welding by P.N.Rao, McGraw HillPublication, 2018

IME 551	**Heat Transfer Lab**	**0L:0T:2P**	**1 Credit**

S. No.	List of Experiments: (At least 8 of the following)
1	To visualized the pool boiling over the heater wire in different regions up to the critical heat flux point at which the wire melts.
2	To find out the thermal conductivity of insulating powder.
3	To determine heat conduction through lagged pipe.
4	To study the unsteady state heat transfer by the Lumped capacitance.
5	To study the temperature distribution along the length of a pin fin under free and forced convection heat transfer.
6	To determine the forced convection heat transfer coefficient for the flow through the given horizontal tube.
7	To determine the natural convection heat transfer coefficient for the vertical tube exposed to atmosphere air.
8	To determine the Stefan Boltzmann Constant for given Material.
9	To determine the emissivity of the non-black surface and compare with the black body.
10	To compare overall heat transfer coefficient for Parallel and Counter flow in a Double pipe Heat Exchanger.
11	To compare LMTD and Effectiveness of Parallel and Counter Flow Heat Exchangers.
12	To study the heat transfer through shell & tube heat exchanger.
13	To find the heat transfer coefficient for Drop wise consideration and Film wise condensation process.

Course Outcomes:

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

COs	Statements
CO1	Apply the concept of conductive heat transfer.
CO2	Apply empirical correlations for both forced and free convection to determine the value of convection heat transfer coefficient.
CO3	Apply the concept of radiation heat transfer for black and grey body.
CO4	Analyze the thermal behaviour of parallel or counter flow heat exchangers.
CO5	Conduct thermal analysis of a heat pipe.

IME 552	Machine Design Lab	0L:0T:2P	1 Credit

A Design of Machine Elements

1. Design a knuckle joint subjected to given tensile load.

2. Design a riveted joint subjected to given eccentric load.
3. Design of shaft subjected to combined constant twisting and bending loads
4. Design a transverse fillet welded joint subjected to given tensile load.
5. Design & select suitable Rolling Contact Bearing for a shaft with given specifications
6. Design a cylinder head of an IC Engine with prescribed parameters.
7. Design of Piston & its parts of an IC Engine

B. Computer Programs for conventional design

Computer and Language

Students are required to learn the basics of computer language such as C/C++/MATLAB so that they should be able to write the computer program.

1. Design a pair of Spur Gear with given specifications to determine its various dimensions using Computer Program in C/C++.
2. Design a pair of Helical Gear with given specifications to determine its various dimensions using Computer Program in C/C++.
3. Design of Sliding Contact Bearing with given specifications & determine its various parameter using Computer Program in C/C++.

Course Outcomes:

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

COs	Statements
CO1	Apply the principles of solid mechanics to design various machine Elements subjected to static and fluctuating loads.
CO2	Write computer programs and validate it for the design of different machine elements
CO3	Evaluate designed machine elements to check their safety.
CO4	Structural design of various I.C. engine Components
CO5	Structural design of various joints and bearings

IME 553	I.C. Engine LAB	0L:0T:2P	1 Credit

S. No.	**List of Experiments:** (At least 8 of the following)
1	Study and working of Two stroke Petrol & Diesel Engine.
2	Study and working of Two stroke Petrol & Diesel Engine.
3	Study the constructional details and components of Internal Combustion Engine.
4	Determination of indicated H.P. of 4-cylinder gasoline engine by Morse Test.
5	Prepare the heat balance of Diesel Engine on single cylinder test rig.
6	Find the volumetric efficiency of engine (single cylinder diesel engine test rig)
7	Performance analysis of four stroke 4-cylinder SI Engine.
8	Study and experiment on gear box
9	Study of fuel supply system.
10	Study and experiment on steering mechanism
11	Study and experiment on differential gear mechanism of rear axle
12	Study and experiment on automobile braking system
13	Study of cooling system in Internal Combustion Engine.
14	Modelling and Simulation of otto and diesel cycle

Course Outcomes:

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

COs	Statements
CO1	Understand the practical operation of 2 stroke and 4 stroke I.C engines using valve timing diagram
CO2	Understand the constructional details and components of IC Engine.
CO3	Conduct performance tests on IC engines and evaluate performance parameter.
CO4	Analyze the performance of multi cylinder engines with the variation of various performances like load and speed.
CO5	Familiarize with the constructional details of automobile components.

Program Elective Course-I

IME 051	I.C. Engine	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	**Introduction to I.C. Engines**: Engine classification and basic terminology, Two and four stroke engines, SI and CI engines, Valve timing diagram, Valve operating mechanism. Thermodynamic analysis of Air standard cycles: Otto cycle, Diesel cycle, Dual cycle, Comparison of Otto, Diesel and Dual cycles, Fuel air cycle, factors affecting the fuel air cycle, Actual cycle. Modeling and simulation of Air standard cycle.	8
II	**SI Engines:** Combustion in SI engine, Flame speed, Ignition delay, Abnormal combustion and it's control. Carburetion, Mixture requirements, Carburetor types, Theory of carburetor, MPFI; Ignition system requirements, Magneto and battery ignition systems, ignition timing and spark plug, electronic ignition.	7
III	**CI Engine:** Combustion in CI engines, Ignition delay, effect of various variable on ignition dlay, Knock and its control, comparison of knocking in CI and SI Engine, Fuel injection in CI engines, Requirements, Types of injection systems, Fuel pumps, Fuel injectors, Injection timings; Turbocharging, Effect of turbocharging on power & emission.	8
IV	**Testing and Performance:** Performance parameters, Measurements methods for Power, Fuel, and air measurement, Testing of SI and CI engines. **Fuels:** Fuels for SI and CI engine, Important qualities of SI and CI engine fuels, Rating of SI engine and CI engine fuels, Dopes, Additives, Gaseous fuels, LPG, CNG, Biogas, Producer gas, Alternative fuels for IC. Introduction to alternate fuels-biofuels, Vegetable oils and Biodiesel, Ethanol, LPG, CNG, Hydrogen,	8
V	**Engine Cooling and Lubrication:** Air cooling and Water-cooling system, Radiators and cooling fans, Lubrication principle, Type of lubrication, properties of lubricants. **Engine Emission and Control:** Pollutant - Sources and types – Effect on environment and human health, formation of NOx, Hydrocarbon Emission, Carbon Monoxide, Particulate Matter emissions Methods of controlling Emissions - Catalytic converters and Particulate Traps - Selective Catalytic Reduction (SCR) - Diesel Oxidation Catalyst (DOC), EGR. Recent trends in IC engine: Homogeneous charge compression ignition engine (HCCI), Gasoline Direct Injection (GDI). Fundamental of fuel cells, hybrid vehicle stack configurations and fuel cell-based hybrid systems.	9

Course Outcomes:

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

COs	Statements
CO1	Understand the working and constructional details of IC engines, analyze air standard cycles, understand the effect on fuel air and actual cycle

CO2	Describe combustion phenomenon in SI, demonstrate abnormal combustion and factors influencing it, interpret subsystems in SI engine
CO3	Describe combustion phenomenon and knocking in CI Engine, compare with SI engine.
CO4	Measure engine operating parameters and calculate performance of engine. Understand concepts of different alternate fuels.
CO5	Describe the pollutant formation its effect and control, Understand the lubrication and ignition system, latest trend and development in IC engine

Text Books:

1. A Course in International Combustion Engines, by Mathur& Sharma, DhanpatRai& Sons.
2. I.C Engine, by Ganeshan, Tata McGraw Hill Publishers.

Reference Books

1. I.C Engine Analysis & Practice by E.F Obert.
2. Internal Combustion Engine Fundamentals, by John B. Heywood, Tata Mcgraw Hill Publishers.
3. Engine Emission, by B. P. Pundir, Narosa Publication.
4. Engineering Fundamentals of Internal Combustion Engines by W.W. Pulkrabek, Pearson Education.
5. Fundamentals of Internal Combustion Engine by Gill, Smith, Ziurs, Oxford & IBH Publishing CO.
6. Fundamentals of Internal Combustion Engines by H.N. Gupta, Prentice Hall of India.

Web Links:

1.https://www.youtube.com/watch?v=CO2StedJtAc&list=PLwdnzlV3ogoXHbVNKWL1BYOo_8PpyNtnC &ab_channel=NPTELIITGuwahati
2. https://ocw.mit.edu/courses/2-61-internal-combustion-engines-spring-2017/
3. https://archive.nptel.ac.in/courses/112/103/112103262/

IME 052	Production & Operations Management	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	**Introduction:** Scope of production management. Production system and resources (machines, tooling, etc.); Types of production (batch, flow and unit), Roles of line supervisors and production managers.	8
II	**Project Management:** Project life cycle: concept phase (RFQ, Quotations, Proposals), Project initiations, DPR preparation (project value, business case development and feasibility study); Project planning (obtaining resources, acquiring financing and procuring required materials); Project team, producing quality outputs, handling risk, acceptance criteria; Project execution (allocation of resources, scheduling, building deliverables); Project Monitoring and control: Project networks, progress review (physical and financial), CPM and PERT, critical path, re-scheduling; Project closure: acceptance of project deliverable; Analytics: Performance, capability aggregation, cost benefit analysis, variability analysis, Output-outcome analysis, project documentation, best practices, and depository.	9
III	**Production Planning and Control:** Production planning, Process planning, Resource planning, demand-utility mapping (production capability index, forecasting models, aggregate production planning, materials requirement planning); Inventory Management: Economic order Quantity, discount models, stochastic inventory models, practical inventory control models, JIT; Supply chain and management.	9
IV	**Factory Management:** Factory layout: line balancing, material flow and handling, Lean and green manufacturing, Human resource management, Training need analysis, Advantage and opportunities for Digitalization, Advanced factory systems: TQM; Important acts, regularities and safety norms, Reliability assessment of processes, Block chain, Energy management, Efficiency & throughput, Overall equipment effectiveness. Process capability, lean manufacturing.	8
V	**Operation Management:** Linear programming, objective function and constraints, graphical method, Simplex and duplex algorithms, transportation assignment; Simple queuing theory models; Traveling Salesman problem; Network models: shortest route, minimal spanning tree, maximum flow model.	8

Course Outcomes:

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

COs	Statements
CO1	To provide knowledge on production management techniques that develop and establish relationship between market demand and production capability.
CO2	To understand the concept of project life cycle and Project planning
CO3	To understand the scientific approach and tools and techniques that assure market competitiveness by ensuring the quality, cost and time
CO4	To understand the factory management: factory lay out and lean manufacturing

CO5	To understand the operation management: Resource planning and their utility

Reference Books:

1. L.J. Krajewski and L.P Ritzmen, Operations Management: Strategy and Analysis, Pearson, 2010.
2. R.B. Chase, F.R. Jacobs and N.J. Aquilano, Operations Management for Competitive Advantage, Tata McGraw Hill, 2011.
3. W. J. Hopp and M. L. Spearman, Factory Physics: Foundations of Manufacturing Management, McGraw Hill International Edition, 2008.
4. Mahadevan. B., Operations Management: Theory and Practice, Pearson, 2015.
5. Taha H. A., Operations Research, 6th Edition, PHI India, 2003.
6. M.P. Poonia, Total Quality Management, Khanna Publishing House, 2022.

IME 053	Mechanical Vibration	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	Introduction, Classification of Vibration Systems, Harmonic motion, Vector representation of harmonic motion, Natural frequency & response, Effects of vibration, superposition of simple harmonic motions, beats, Fourier analysis-analytical method. Single Degree Freedom System, Equation of motion, Newton's method, D'Alembert's principle, Energy method etc., Free vibration, Natural frequency, Equivalent systems, Displacement, Velocity and acceleration, Response to an initial disturbance, Torsional vibrations, Damped vibrations, Vibrations of systems with viscous damping, Logarithmic decrement, Energy dissipation in viscous damping.	8
II	Single Degree Freedom: Forced Vibration Forced vibration, Harmonic excitation with viscous damping, steady state vibrations, Forced vibrations with rotating and reciprocating unbalance, Support excitation, Vibration isolation, Transmissibility, Vibration measuring instruments, Displacement, velocity, and acceleration measuring instruments	8
III	Two Degree Freedom systems Introduction, Principal modes, Double pendulum, Torsional system with damping, Coupled system, Principle of vibration absorber, Undamped dynamic vibration absorbers, Torsional vibration absorber, Centrifugal pendulum absorbers, Vibration isolators and Dampers.	8
IV	Multi-degree Freedom system: Exact Analysis, Undamped free and forced vibrations of multi-degree freedom systems, influence coefficients, Reciprocal theorem, Torsional vibration of multi-degree rotor system, Vibration of gear system, Principal coordinates, Continuous systems-Longitudinal vibrations of bars, Torsional vibrations of circular shafts. Multi Degree Freedom system: Numerical Analysis by Rayleigh's method, Dunkerley's, Holzer's and Stools methods, Rayleigh-Ritz method.	8
V	Critical speed of shafts, Whirling of uniform shaft, Shaft with one disc with and without damping, Multi-disc shafts, Secondary critical speed. Industrial case studies (any two) involving mechanical vibrations, their impact and performance analysis. Introduction to the vibration analysis using MATLAB.	8

Course Outcomes:

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

COs	Statements
CO1	Understand fundamentals of mechanical vibrations along with their classification
CO2	Analyze, predict and measure the performance of systems undergoing single, two and multiple DOF.
CO3	Design systems with optimized vibration absorption capabilities.
CO4	Apply the fundamentals to the real-life problems like whirling of shaft
CO5	Solve complicated mathematical models using Numerical methods and software applications.

Reference Books:

1.Mechanical Vibrations- V.P. Singh, Dhanpatrai & Co.
2. Mechanical Vibrations- G. K. Grover, Jain Brothers, Roorkee.
3. Mechanical Vibrations- Kelly
4. Mechanical Vibrations- Tse, Morse & Hinkle
5. **Case study Reference#1**: https://www.ijstr.org/final-print/july2018/Vibration-Analysis-Of-Rotating-Machines-With-Case-Studies.pdf
6. **Case study Reference#2:**
https://www.researchgate.net/publication/254227083_Case_studies_of_vibrations_in_structures
7. Case study Reference#3:
https://pdfs.semanticscholar.org/f2b6/39990c4ba52706f43d02fe1c59b9c3fabf2a.pdf

IME 054	Tribology	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	**Lubrication and Lubricants** Introduction to tribology, tribology in industry, basics modes of lubrication, oil viscosity, temperature and pressure dependence of viscosity, Viscosity index, viscosity measurement, properties of lubricants, temperature characteristics of lubricants, lubricant impurities and contaminants, mineral oils-based lubricants, synthetic oils-based lubricants, emulsions and aqueous lubricants, greases, and lubricant additives.	8
II	**Friction and Wear** Friction-causes of friction, theories of dry friction; adhesion theory, abrasive theory, junction growth theory, laws of rolling friction, friction measurement, friction instabilities. Wear- classification; abrasive wear, erosive wear, cavitation wear, adhesive wear, corrosive wear, oxidative wear, fatigue wear, factors affecting wear, measurement of wear, theories of wear, approaches to friction control and wear prevention.	8
III	**Lubrication of Bearings** Theory of hydrodynamic lubrication, mechanism of pressure development in oil film, jet lubrication, mist lubrication, lubrication utilizing under race passage, concept of journal bearing, minimum oil film thickness, porous bearings, flat plate thrust bearing, tilting pad bearings, hydrostatic lubrication, squeeze film lubrication, elasto-hydrodynamic lubrication, rolling element bearings, gas lubricated bearings, and hybrid bearings.	8
IV	**Solid Lubrication and Surface Treatment** Lubrication by solids, friction and wear characteristics of lamellar solids, reduction of friction by soft metallic films, deposition methods of solid lubricants, techniques for producing wear resistant coatings, characteristics of wear resistant coatings.	8
V	**Friction, Lubrication and Wear in Kinematic pairs** The concept of friction angle, friction stability, friction in slideways, friction in screws with square threads, friction in screws with triangular threads, mechanism and operation of plate clutch, cone clutch, rim clutch, centrifugal clutch, and belt drives, tribo design aspects of labyrinth seals, analysis of line contact lubrication, analysis of point contact lubrication, cam follower system, traction in the contact zone, and hysteresis losses.	8

Course Outcomes:

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

COs	Statements
CO1	Understand the types of lubricants for different applications
CO2	Identify and explain various friction and wear mechanisms.
CO3	Describe lubrication methods in different bearings.
CO4	Study the surfaces coating techniques for reduction of wear.

CO5	Analyze the impact of friction in various kinematic pairs.

Reference Books:

1. Fundamentals of Engineering Tribology with Applications by Harish Hirani, Cambridge English (2017)
2. Applied Tribology (Bearing Design and Lubrication), by Michael M Khonsari, John Wiley & Sons (2001).
3. Principles of Tribology, by J Halling, The Macmillan Press Ltd,London, (1975).
4. Friction, Wear, Lubrication:A textbook in Tribology, by Ludema K C, CRC Press, (2010).
5. Fundamentals of Machine Elements, B.J. Hamrock, B.O. Jacobson & S.R. Schmid, McGraw-Hill Inc., (1998).
6. Fundamentals of Mechanical Component Design, by K.S. Edwards & R.B. McKee, McGraw-Hill Inc., (1991).
7. Mechanical Engineering Design by J.E. Shigley and C R Mischke, Tata McGraw-Hill Publishing Company Limited, (2003).
8. Tribophysics, by N.P. Suh Prentice-Hall, (1986).
9. Friction, Wear, Lubrication: A Textbook in Tribology, by Kenneth C Ludema, LayoAjayi, CRC Press (2019).

Program Elective Course-II

IME 055	Mechatronics	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	Introduction: Evolution of Mechatronics, Elements of Mechatronics system, Measurement Systems, Dynamics response of systems	8
II	Controllers: Control Systems, Feedback, open loop and closed loop control Basic control actions. Proportional, integral and derivative control. Op Amp based PID controller, Transfer function, block diagram reduction	8
III	Sensors & Transducers: Performance terminology, Various types of sensors and transducers and their applications. Signals and Signal conditioning: Operational amplifiers and its applications, analogue to digital and digital to analogue conversion. Data acquisition	9
IV	Microprocessors: Logic building and processing, logic gates, combinational and sequential logic, fuzzy logic, microprocessor and its programming, microcontroller. Introduction to ladder programming (for PLCs like Allen Bradley, Siemen etc used in industries)	9
V	Actuation systems: Mechanical actuators, Applications, Electrical actuators and their applications, Hydraulic and pneumatic actuation systems. Hydraulic and pneumatic circuit for industrial applications	8

Course Outcomes:

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

COs	Statements
CO1	Identify various components of a mechatronic system and their correlations and explain dynamic characteristics of the system
CO2	Devise mathematical model various closed loop control systems and explain their working
CO3	Select transducers, sensors, operational amplifiers, signal condition and data acquisition systems for various applications and explain their working
CO4	Explain the working of various components and internal architecture of microprocessors and microcontrollers and write program to accomplish simple tasks
CO5	Select various mechanical, electrical, hydraulic and pneumatic actuators for a particular application.

Reference Books:

1. W. Bolton, Mechatronics A multidisciplinary approach, Pearson India, Chennai, 4th Ed., 2016.
2. D.G. Alciatore, M.B. Histand, Introduction to mechatronics and measurement systems, McGraw Hill Education (India) Private Ltd., Chennai, 4th Ed., 2014
3. K. Ogata, Modern Control Engineering, Pearson Education, New Delhi, 4th Ed., 2002.
4. John Crisp, Introduction to Microprocessors and Micontrollers, Elsevier, 2nd Edition, 2004

5. Norman S Nise, Control Systems Engineering, John Wiley and Sons, Inc., USA, 6th Ed., 2011.
6. C.A. Alexander, M.N.O. Sadiku, Fundamentals of Electrical circuits, McGraw Hill Education, USA, 3rd Ed.
7. Andrew Parr, Hydraulics and Pneumatics, Elsevier, 3rd Edition, 2011.

IME 056	Artificial Intelligence	3L:0T:0P	3Credits

Unit	Topics	No. of Hours
I	Introduction of Artificial Intelligence, Intelligent Agents, and Behaviors of Artificial Agents, Structure of Intelligent Agents. Problem solving and state space search, Uninformed Search, Heuristic search, Best- First Search, Heuristic Functions, Constraints satisfaction problem, Iterative Improvement Algorithms. (Recommended lab practice sessions: Games as Search Problems, Alpha-Beta Pruning, State-of-the-Art Game Programs.)	9
II	Introduction to Knowledge Representation, Propositional Logic, 1st order logic-I, 1st order logic-II, Inference in First-Order Logic, Using First-Order Logic, Building a Knowledge Base, Logical Reasoning Systems; Indexing, Retrieval, and Unification, Inference in FOL-II, Answer Extraction.	8
III	Procedural control of reasoning, reasoning under uncertainty, Bayesian Networks, Decision Networks, Uncertain knowledge and reasoning, The Axioms of Probability, Bayes' Rule and Its Use, Probabilistic Reasoning Systems, Making Simple Decisions, Making Complex Decisions, Introduction to Planning, Practical Planning and Acting, Inductive Learning, Learning from Observations.	9
IV	Neural Networks: Learning in Neural Networks, How the Brain Works, Perceptron, Multilayer Feed- Forward Networks, Applications of Neural Networks, Introduction to Learning, Kinds of Learning, Supervised and Unsupervised Learning, Clustering, Reinforcement Learning. Learning a Function, Aspects of Function Learning, and Types of function learning aspects: Memory, Averaging and Generalization, Example problems based on Function Learning. Learning methods, Nearest Neighbor, Decision Trees, and Neural Networks.	8
V	Intelligent Agents, Types of Communicating Agents, A Communicating Agent, Practical Natural Language Processing: Practical Applications, Efficient Parsing, Scaling Perception: Image-Processing Operations for Early Vision, Using Vision for Manipulation and Navigation, Speech Recognition. Robotics: Tasks: What Are Robots Good For? Parts: What Are Robots Made of? Architectures, Configuration Spaces: A Framework for Analysis, Navigation and Motion Planning	8

Course Outcomes:

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

COs	Statements
CO1	Understand concepts of Artificial Intelligence
CO2	Understand Knowledge representation
CO3	Apply concepts of Learning methods
CO4	Analyse Decision Networks
CO5	Understand the intelligent agents and build planning graphs

Text Book:

1. Stuart Russell, Peter Norvig, “Artificial Intelligence – A Modern Approach”, Pearson Education

Reference Books:

2. Elaine Rich and Kevin Knight, “Artificial Intelligence”, McGraw-Hill
3. E Charniak and D McDermott, “Introduction to Artificial Intelligence”, Pearson Education
4. Dan W. Patterson, “Artificial Intelligence and Expert Systems”, Prentice Hall of India

IME 057	Non-Destructive Testing	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	Introduction to NDT, DT, advantages & limitations of NDT, classification of NDT methods, Comparison with DT, Terminology, Flaws and Defects. Scope of NDT, Codes, Standards and Certifications in NDT. **Visual Inspection–** Equipment used for visual inspection, Borescopes, Application of visual inspection tests in detecting surface defects and their interpretation, advantages & limitations of visual inspection, Visual Inspection in Welding.	8
II	**Liquid Penetrant Testing –** Principle, Scope, Testing equipment, Advantages, Limitations, types of penetrants and developers, standard testing procedure, Zyglo test, Illustrative examples and interpretation of defects. **Magnetic Particle Inspection –** Principle, Scope, testing equipment, Advantages, Limitations, Application of MPI& standard testing procedure, DC & AC magnetization, Skin Effect, different methods to generate magnetic fields, Illustrative examples and interpretation of defects.	8
III	**Radiographic Testing –** Introduction to electromagnetic waves and radioactivity, various decays, Attenuation of electromagnetic radiations, Photoelectric effect, coherent scattering and Incoherent scattering, Beam geometry. **X-ray Radiography –** Principle, equipment & methodology, applications, source, types of radiations and limitations; γ-ray Radiography – Principle, equipment, γ-ray source & technique; Radiography Image Quality Indicators, Film Processing, advantages of γ-ray radiography over X-ray radiography. Precautions against radiation hazards.	8
IV	**Ultrasonic Testing –** Introduction, Principle, Piezoelectricity and Piezoelectric Transducers, Wave propagation, Ultrasonic probes, selection of angle probes, Acoustic Impedance, Reflection and transmission coefficient, Snell's law, standard testing procedure & calibration, advantages & limitations. Data representation - A-scan, B-scan, C-scan. Applications in inspection of welded joints, castings, forgings and dimensional measurements. Introduction to TOFD& Phased Array Ultrasonic Testing.	8
V	**Special NDT Techniques:** Eddy Current Inspection– Introduction, Principle, Methods, scope, Equipment, types of probes, Sensitivity, standard testing procedure, advanced ECT methods, advantages and limitations. Acoustic Emission Technique– Introduction, Types of AE signal, Principle, Advantages & Limitations, Interpretation of Results, Applications. Holography, Thermography– Introduction, Principle, advantages, limitations and applications, advantages, limitations and applications	8

Course Outcomes:

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

COs	Statements
CO1	Understand the concept of destructive and Non-destructive testing methods.
CO2	Explain the working principle and application of die penetrant test and magnetic

	particle inspection
CO3	Understand the working principle of eddy current inspection
CO4	Apply radiographic techniques for testing
CO5	Apply the principle of Ultrasonic testing and applications in medical and engineering areas

Reference Books:

1. Non-Destructive Testing and Evaluation of Materials, by- Prasad, McGraw Hill Education.
2. Practical Non-destructive Testing, by- Baldev Raj, T. Jayakumar, M. Thavasimuthu, Woodhead Publishing.
3. Non-Destructive Testing Techniques, by- Ravi Prakash, New Age International.
4. Non destructive Testing Handbook, by Robert C. McMaster, American Society for Nondestructive.
5. Introduction to Non destructive Testing: A Training Guide, by- Paul E. Mix, wiley.
6. Electrical and Magnetic Methods of Non-destructive Testing, by- J. Blitz, springer.
7. Practical non destructive testing by Raj, Baldev.
8. Basics of Non-Destructive Testing, by Lari& Kumar, KATSON Books.
9. ASME Sec. V, boiler and pressure vessel code

IME 058	Product Design and Development	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	Engineering design process stages and activities, categories of product design, opportunity analysis, need analysis and information gathering methods	8
II	Concept generation and development, selection, and evaluation methods, creative thinking methods, decision making models, product design specifications, benchmarking	8
III	Product design stage, identification of alternatives, product architecture, modular and integral designs, process design, prototyping, modelling and simulation	8
IV	Industrial design, detail design, design for manufacturing and environment, robust design, cost evaluation, legal and ethical issues	8
V	Materials selection, design with materials, material selection with decision matrices, design for recycling and reusability	8

Course Outcomes:

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

COs	Statements
CO1	Understand to think, design and develop new parts/products.
CO2	Understand the development and product design
CO3	Improve quality of processes / products by applying the specified procedures of product development
CO4	Understand the existing designs, synthesize and analyze the information for modification or addition in the existing components
CO5	Understand the selection of material for recycling and reusability

Reference Books:

1. Engineering Design, George E. Dieter and Linda C. Schmidt, Mc Graw hill.
2. Product Design and Development, Karl T. Ulrich and Steven D. Eppinger, Mc Graw Hill.
3. Product Design for Engineers, Devdas Shetty, Cengage Learning.
4. Engineering Design Methods, Nigel Cross, Wiley.
5. Product Design, Techniques in Reverse Engineering and New Product Development, Kevin Otto, Kristin wood, Pearson Education

IME 601	Refrigeration and Air Conditioning	3L:1T:0P	4 Credit

Unit	Topics	No. of Hours
I	Refrigeration: Introduction to refrigeration system, Methods of refrigeration, Carnot refrigeration cycle, Refrigerator and Heat Pump, C.O.P. Air Refrigeration cycle: Open and closed air refrigeration cycles, Bell Coleman or Reversed Joule air refrigeration cycle, Need of Aircraft refrigeration, Classification of aircraft refrigeration system. Boot strap refrigeration, Regenerative, Reduced ambient, Dry air rated temperature (DART).	8
II	Vapour Compression System: Reversed vapour Carnot cycle, limitation of Reversed vapour Carnot cycle, Simple vapour compression cycle, Analysis of vapour compression cycle, Effect of change in suction and discharge pressures on C.O.P, Effect of sub cooling of condensate & superheating of refrigerant vapour on C.O.P of the cycle, Actual vapour compression refrigeration cycle, Multistage System: Multistage vapour compression system requirement, Different configuration of multi pressure system, Removal of flash gas, Intercooling, Multi evaporator system, Cascade system	9
III	Vapour Absorption system; Working Principal of vapour absorption refrigeration system, Comparison between absorption & compression systems, Elementary idea of refrigerant absorbent mixtures, Temperature – concentration diagram & Enthalpy – concentration diagram , Adiabatic mixing of two streams, Ammonia – Water vapour absorption system, Lithium- Bromide water vapour absorption system, Comparison, Three fluid system Refrigerants: Classification of refrigerants, Nomenclature, Desirable properties of refrigerants, Common refrigerants, Secondary refrigerants, and Environment friendly refrigerants, Anti-freeze solution, Phase changing materials, Ozone layer depletion and global warming considerations of refrigerants, Selection of refrigerants, Future Refrigerants like Hydrofluoro-Olefines	8
IV	Air Conditioning: Introduction to air conditioning, Psychrometric properties and their definitions, Psychrometric chart, Different Psychrometric processes, , cooling towers & humidifying efficiency, Thermal analysis of human body, Effective temperature and comfort chart, Comfort and Industrial air conditioning Refrigeration, Cooling and heating load calculations, Selection of inside & outside design conditions, Air-conditioning calculations, Cooling load estimation Sensible heat factor , By pass factor, Grand Sensible heat factor (GSHF), Apparatus dew point (ADP).	9
V	Refrigeration System Equipment: Compressors, Condensers, Expansion Devices and Evaporators, Elementary knowledge of transmission and distribution of air through ducts and fans, Other systems: Cryogenic liquefaction and refrigeration systems, non-conventional refrigeration systems (Thermo-electric, Vortex and Pulse Tube, Gas cycles, Absorption chillers, Steam jet refrigeration system, Magnetic refrigeration system).	8

Course Outcomes:

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

COs	Statement
CO1	Apply the basics concepts of thermodynamics for Air-refrigeration system.
CO2	Understand the construction and working of single/multi-stage vapour compression Refrigeration systems
CO3	Understand the vapor absorption refrigeration system and its applications.
CO4	Analyze different processes involved in Air-Conditioning to evaluate heating load calculations
CO5	Understand refrigeration equipment's function and non-conventional refrigeration systems

Reference Books:

1. Refrigeration and Air conditioning by C.P Arora, McGraw-Hill
2. Refrigeration and Air conditioning, by Manohar Prasad, New Age International (P) Ltd. Pub.
3. Refrigeration and Air conditioning by R.C. Arora, PHI
4. Principles of Refrigeration by Roy J. Dossat. Pearson Education
5. Refrigeration and Air conditioning by Stoecker& Jones. McGraw-Hill
6. Refrigeration and Air conditioning by Arora & Domkundwar. Dhanpat Rai
7. Thermal Environment Engineering. By Kuhen, Ramsey &Thelked

IME 602	Theory of Machine	3L:1T:0P	4 Credit

Unit	Topics	No. of Hours
I	Introduction, mechanisms and machines, kinematics and kinetics, types of links, kinematic pairs and their classification, types of constraint, degrees of freedom of planar mechanism, Grubler's equation, mechanisms, inversion of four bar chain, slider crank chain and double slider crank chain. **Velocity analysis:** Introduction, velocity of point in mechanism, relative velocity method, velocities in four bar mechanism, instantaneous center. **Acceleration analysis:** Introduction, acceleration of a point on a link, acceleration diagram, Corioli's component of acceleration, crank and slotted lever mechanism	8
II	**Cams:** Introduction, classification of cams and followers, cam profiles for knife edge, roller and flat faced followers for uniform velocity, uniform acceleration **Gears and gear trains:** Introduction, classification of gears, law of gearing, tooth forms and their comparisons, systems of gear teeth, length of path of contact, contact ratio, minimum number of teeth on gear and pinion to avoid interference, simple, compound, reverted and planetary gear trains, sun and planet gear train	9
III	**Force analysis:** Static force analysis of mechanisms, D'Alembert's Principle, dynamics of rigid link in plane motion, dynamic force analysis of planar mechanisms, piston force and crank effort. Turning moment on crankshaft due to force on piston, turning moment diagrams for single cylinder double acting steam engine, four stroke IC engine and multi-cylinder engines, Fluctuation of speed, Flywheel.	8
IV	**Balancing:** Introduction, static balance, dynamic balance, balancing of rotating masses, two plane balancing, graphical and analytical methods, balancing of reciprocating masses, balancing of single cylinder engine. **Governors:** Introduction, types of governors, characteristics of centrifugal governors, gravity controlled and spring controlled centrifugal governors, hunting of centrifugal governors, inertia governors. Effort and Power of governor	9
V	**Brakes and dynamometers:** Introduction, Law of friction and types of lubrication, types of brakes, effect of braking on rear and front wheels of a four-wheeler, dynamometers, belt transmission dynamometer, torsion dynamometer, hydraulic dynamometer Gyroscope: Space motion of rigid bodies, angular momentum, gyroscopic couples, gyroscopic stabilization, ship stabilization, stability of four wheel and two-wheel vehicles moving on curved paths.	8

Course Outcomes:

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

COs	Statements
CO1	Understand the principles of kinematics and dynamics of machines.
CO2	Apply the concept of gear, gear train and flywheel for power transmission

CO3	Apply dynamic force analysis for different mechanism
CO4	Apply the concepts of governors in fluctuation of load balance rotating & reciprocating masses in machines.
CO5	Apply the concepts of gyroscope, governors in fluctuation of load and brake & dynamometer in power transmission

Reference Books:

1. Kinematics and dynamics of machinery: Wilson and Sadler, Third edition, Pearson.
2. Theory of Mechanisms and Machines: Amitabh Ghosh and Ashok Kumar Mallik, Third Edition Affiliated East-West Press.
3. Theory of Machines and Mechanisms: Joseph Edward Shigley and John Joseph Uicker, Jr. Oxford University Press
4. Kinematics and dynamics of machinery: R L Norton, McGraw Hill
5. Theory of Machines: S.S. Rattan, McGraw Hill
6. Theory of Machines: Thomas Bevan, CBS Publishers.

IME 603	Industrial Engineering	3L:1T:0P	4 Credit

Unit	Topics	No. of Hours
I	**Overview of Industrial Engineering:** Types of production systems, concept of productivity, productivity measurement in manufacturing and service organizations, operations strategies, liability and process design. **Facility location and layout:** Factors affecting facility location; principle of plant layout design, types of plant layout; computer aided layout design techniques; assembly line balancing; materials handling principles, types of material handling systems, methods of process planning, steps in process selection, production equipment and tooling selection, group technology, and flexible manufacturing.	9
II	**Production Planning and control:** Forecasting techniques – causal and time series models, moving average, exponential smoothing, trend and seasonality; aggregate production planning; master production scheduling; materials requirement planning (MRP) and MRP-II; routing, scheduling and priority dispatching, concept of JIT manufacturing system **Project Management:** Project network analysis, CPM, PERT and Project crashing.	8
III	**Inventory control:** Methods of depreciation; break-even analysis, techniques for evaluation of capital investments, financial statements, time-cost trade-off, resource levelling; Inventory functions, costs, classifications, deterministic inventory models, perpetual and periodic inventory control systems, ABC analysis, and VED analysis. **Queuing Theory:** Basis of Queuing theory, elements of queuing theory, Operating characteristics of a queuing system, Classification of Queuing models.	9
IV	**Work System Design:** Taylor's scientific management, Gilbreths's contributions; work study: method study, micro-motion study, principles of motion economy; work measurement –time study, work sampling, standard data, Predetermined motion time system (PMTS); ergonomics; job evaluation, merit rating, incentive schemes, and wage administration.	8
V	**Operational Analysis:** Formulation of LPP, Graphical solution of LPP, Simplex Method, Sensitivity Analysis, degeneracy and unbound solutions. transportation and assignment models; Optimality test: the stepping stone method and MODI method, simulation.	8

Course Outcomes:

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

COs	Statements
CO1	Understand the concept of production system, productivity, facility and process planning in various industries
CO2	Apply the various forecasting and project management techniques
CO3	Apply the concept of break-even analysis, inventory control and resource utilization using queuing theory

CO4	Apply principles of work study and ergonomics for design of work systems
CO5	Formulate mathematical models for optimal solution of industrial problems using linear programming approach

Reference Books:

1. Industrial Engineering and Production Management by Martand T Telsang S. Chand Publishing
2. Industrial Engineering and Production Management by M. MahajanDhanpatRai& Co. (P) Limited
3. Industrial Engineering and Management by Ravi Shankar, Galgotia Publications Pvt Ltd
4. Production and Operations Management by Adam, B.E. & Ebert, R.J., PHI
5. Product Design and Manufacturing by Chitale A.V. and Gupta R.C., PHI
6. Operations Research Theory & Applications by J K Sharma, Macmillan India Ltd,
7. Production Systems Analysis and Control by J.L.Riggs, John Wiley & Sons
8. Automation, Production Systems & Computer Integrated Manufacturing by Groover, M.P. PHI
9. Operations Research, by A.M. Natarajan, P. Balasubramani, A. Tamilarasi, Pearson Education
10. Operations Research by P. K. Gupta and D. S. Hira, S. Chand & Co.

IME 651	Refrigeration and Air Conditioning Lab	0L:0T:2P	1 Credit

S. No.	List of Experiments: (At least 8 of the following)
1	Experiment on refrigeration test rig and calculation of various performance parameters.
2	Experiment on air-conditioning test rig & calculation of various performance parameters.
3	Study of Psychrometer and determination of humidity of air using Sling Psychrometer.
4	To study and perform experiment on vapour absorption apparatus.
5	To study the air washer and perform different psychometric processes on air washer.
6	Study of desert coolers and determine the change in temperature and humidity of ambient air.
7	Handling, use and familiarization with refrigeration tools and accessories such as: Tube cutter;
8	Tube bender [spring type]; Flaring tool; Swaging tool; Pinch off etc.
9	Study of window air conditioner.
10	Study of Hermetically sealed compressor.
11	To study basic components and control devices of refrigeration and air-conditioning system.
12	Experiment on Ice-plant and calculation of various performance parameters.
13	Visit of a central air conditioning plant and its detailed study.

Course Outcomes:

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

COs	Statements
CO1	Determine the performance of different refrigeration and air-conditioning systems
CO2	Apply the concept of psychrometry on different air-cooling systems.
CO3	Explain the working of practical applications of RAC systems.
CO4	Explain about different equipment's used in refrigeration and air-conditioning systems
CO5	Explain the use of different control systems and tools used in RAC

IME 652	Theory of Machine Lab	0L:0T:2P	1 Credit

S. No.	List of Experiments: (At least 8 of the following)
1	To study various types of kinematics links, pairs, chains & Mechanisms
2	To study Whitworth Quick Return Motion Mechanisms, Reciprocating Engine Mechanism, and Oscillating Engine Mechanism
3	To study of inversions of four bar linkage
4	To study of inversions of single/double slider crank mechanisms
5	To study various types of gear (Helical, cross helical, worm, bevel gear) and gear profile (involute and cycloidal) and condition for interference Helical, cross helical, worm, bevel gear
6	To compute the output velocity in various gear trains
7	To study gyroscopic effects through models
8	To determine gyroscopic couple on Motorized Gyroscope
9	To perform experiment on dead weight type governor to prepare performance characteristic Curves, and to find stability & sensitivity
10	To perform experiment on spring-controlled governor to prepare performance characteristic Curves, and to find stability & sensitivity
11	To determine whirling speed of shaft theoretically and experimentally
12	To perform the experiment for static / dynamic balancing
13	To perform experiment on brake
14	To perform experiment on clutch
15	To perform the experiment for static / dynamic balancing

Course Outcomes:

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

COs	Statements
CO1	Demonstrate various mechanisms, their inversions and brake and clutches in automobiles
CO2	Apply cam-follower mechanism to get desired motion of follower.
CO3	Apply the concepts of gears and gear train to get desired velocity ratio for power transmission.
CO4	Apply the concept of governors to control the fuel supply in engine.
CO5	Determine the balancing load in static and dynamic balancing problem

IME 653	Fluid Machinery Lab	0L:0T:2P	1 Credit

S. No.	**List of Experiments:** (At least 8 of the following)
1	To verify Impulse-momentum principle for impact of jet on a stationary vane.
2	To study the operation and performance of a Pelton wheel.
3	To study the operation and performance of a Francis turbine.
4	To study the operation and performance of a Kaplan turbine.
5	To study the performance characteristics of a single stage centrifugal pump.
6	To obtain the performance characteristics of a reciprocating pump.
7	To study the performance of hydraulic ram under varying condition of head.
8	Demonstration of Working Model of Hydraulic Brake.
9	Design the Impeller of Centrifugal Pump Using Single Arc Method Through Auto Cad.
10	Design the Casing of Impeller Pump Through Auto Cad.
11	Visit to hydraulic power station/Municipal water pump house and case studies.
12	CFD simulation of hydro-turbine.
13	CFD simulation of pump.

Course Outcomes:

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

COs	Statements
CO1	Work out the hydrodynamic force by liquid jet on plane surface and curved vanes for static and dynamic conditions.
CO2	Study the development of hydropower and its advantages over other types of power development.
CO3	Examine the performance and characteristics curve of impulse and reaction turbine.
CO4	Describe the construction, working and performance testing of centrifugal and reciprocating pump.
CO5	To familiarize with the construction and working of different types of hydraulic machines and achieve the knowledge to test their performance.

Program Elective Course-III

IME 061	Fluid Machinery	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	**Impact of jet:** Introduction, impulse-moment principle, impact of jet on fixed and moving flat/inclined plates/curved vane, jet striking on curved vane tangentially at one tip and leaving at another end, force exerted by jet on a hinged plate. **Computational Fluid Dynamics (CFD):** Introduction and fundamentals, equations of motion, solution procedure, grid generation and grid-independence, boundary conditions, CFD simulation on impact of jet.	8
II	**Hydro-turbines:** Classification of turbines, impulse turbines, working and analysis of Pelton turbine, velocity triangles, power, and efficiency calculations. Francis and Kaplan turbines, power and efficiency calculations, draft tube, cavitation, specific speed, selection of hydro-turbines, principles of similarity, unit and specific quantities, performance characteristics, CFD simulation of hydro-turbine.	9
III	**Centrifugal Pumps:** Pump classification and selection criterion, construction and working, velocity vector diagrams, work done by impellor, head of centrifugal pump, pressure rise in the impeller, pump losses and efficiencies, minimum starting speed, design consideration, multistage pumps, specific speed, model testing, performance characteristics, net positive suction head, cavitation, priming, troubles in centrifugal pumps and their causes, CFD simulation of centrifugal pump.	9
IV	**Positive displacement pumps:** Introduction, working principle, coefficient of discharge and slip, effect of friction and acceleration of piston on velocity and pressure in the suction and delivery pipes, effect of variation of velocity in suction and delivery pipe, indicator diagrams, effect of acceleration in suction and delivery pipe on indicator diagram, Air vessels, performance characteristics of reciprocating pump, CFD simulation of reciprocating pump.	8
V	**Hydraulic systems:** Hydraulic press, hydraulic accumulator, hydraulic crane, hydraulic jack, hydraulic lift, hydraulic ram, fluid couplings, fluid torque converter and air lift pump. **Fluidics:** Fluidics terminology, types of fluid logic element, mechanical, interacting jet, Turbulence Amplifier, Industrial Type Turbulence Amplifier, Vortex Amplifier, 3rd generation fluidics. **Artificial Intelligence (AI):** Monitoring/governing of hydraulic turbines/pump by using artificial intelligence techniques.	8

Course Outcomes:

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

COs	Statements

CO1	Evaluate the forces exerted by a jet of fluid on vanes of different shapes under static and dynamic condition.
CO2	Analyze the performance characteristics of impulse and reaction turbine.
CO3	Comprehend the working of different types of pumps and work out the performance of centrifugal pump.
CO4	To familiarize with the construction and working of Reciprocating pumps and achieve the knowledge to test their performance.
CO5	Implementation of CFD/AI indifferent hydraulic system designs.

Reference Books:

1. Lal, Jagdish, "Hydraulic Machines", Metropolitan Book Co. Pvt. Ltd., 2016.
2. Hydraulics and Fluid mechanics - Dr. P. N. Modi & Dr. S. M. Seth
3. Rajput, R K, "Hydraulic Machines", S. Chand & co Ltd., 2016.
4. Kumar, D. S., "Hydraulic Machines", Khanna Publishers, 2010.
5. Addison, Thomas, "Applied Hydraulics", CBS Publishers, 2003.
6. Philip, Gerhart and Wright Terry, "Fluid Machinery- application Selection and Design", CRS.
7. Yunus A. Cengel, John M. Cimbala, "Fluid Mechanics- Fundamentals and Applications", 2018.

IME 062	Gas Dynamics and Jet Propulsion	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	Compressible flow, definition, Mach waves and Mach cone, stagnation states, Mass, momentum and energy equations of one-dimensional flow.	8
II	Isentropic flow through variable area ducts, nozzles and diffusers, subsonic and supersonic flow variable area ducts, choked flow, Area-Mach number relations for isentropic flow.	8
III	Non-isentropic flow in constant area ducts, Rayleigh and Fano flows, Normal shock relations, oblique shock relations, isentropic and shock tables.	8
IV	Theory of jet propulsion, thrust equation, thrust power and propulsive efficiency, Operating principle and cycle analysis of ramjet, turbojet, turbofan and turboprop engines.	8
V	Types of rocket engines, propellants & feeding systems, ignition and combustion, theory of rocket propulsion, performance study, staging, terminal and characteristic velocity, space flights.	8

Course Outcomes:

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

COs	Statements
CO1	Understand the concept of compressible fluid flow and flow through variable area ducts.
CO2	Understand the basic principle and types of jet and rocket propulsion.
CO3	Apply the basic laws for the investigation of flow through ducts.
CO4	Apply the basic laws for the thermodynamics analysis of jet and rocket propulsion.
CO5	Analyze the compressible flow through variable area ducts. K4

Reference Books:

1. Ahmed F. El-Sayed, Aircraft Prpoulsion and Gas Turbine Engines, CRC Press, 2008.
2. H.S. Mukunda, “Understanding Aerospace Chemical Propulsion”, Interline Publishing,2004.
3. Hill P. and Peterson C., Mechanics & Thermodynamics of Propulsion, Addison Wesley,1992.
4. Zucrow N. J., Aircraft and Missile Propulsion, Vol.I& II, John Wiley, 1975.
5. Sutton G.P., Rocket Propulsion Elements, John Wiley, New York, 1986.

IME 063	Computer Integrated Manufacturing	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	**Introduction to Computer Integrated Manufacturing (CIM):** Introduction to CAD, CAM, CIM, Automated Manufacturing system; Need of automation, Basic elements of automation, Levels of automation, Automation Strategies, Advantages & disadvantages of automation, Historical development and future trends. Computer Integrated Manufacturing, Computers in manufacturing industries	8
II	**Principles of Computer Graphics:** Point plotting, drawing of lines, Bresenham's circle algorithm. Transformation in Graphics:2D transformations – rotation, scaling, translation, mirror, reflection, shear – homogeneous transformations – concatenation,3D transformations. **Curves:** Introduction to Hermite cubic splines, Bezier curves, B-spline curves, NURBS. **Surface Modeling:** Polygon surfaces, Quadric surfaces, Super quadric surfaces and blobby objects **Solid modeling:** Boolean set operations, Primitive instancing, Sweep representation, Boundadry representation, Constructive solid geometry	9
III	**Computer Aided Manufacturing:** NC in CAM – Principal types of CNC machine tools and their construction features – tooling for CNC – ISO designation for tooling – CNC operating system Programming for CNC machining – coordinate systems – manual part programming – computer assisted part programming.	8
IV	**Group Technology:** Group technology, Cellular Manufacturing, CAPP – Variant and Generative systems -Concurrent Engineering and Design for Manufacturing. **Flexible Manufacturing System:** characteristics – economics and technological justification – planning, installation, operation and evaluation issues – role of group technology and JIT in FMS – typical case studies future prospects, Industry 4.0. **Robotics:** Classification and specification – drive and controls – sensors - end effectors - grippers- tool handling and work handling – machine vision – robot programming concepts – case studies in assembly.	9
V	**Data and information in CIM:** Management information system in CIM environment, MRP – MRP II – ERP- Capacity planning. **Material handling in CIM environment:** Types – AGVS – AS/RS – Swarf handling and disposal of wastes –single and mixed mode assembly lines – quantitative analysis of assembly systems. **Rapid prototyping:** Need for rapid prototyping, Basic principles and advantages of RP, General features and classifications of different RP techniques with examples.	8

Course Outcomes:

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

COs	Statements
CO1	Understand the basic concepts of automation, computer numeric control machining
CO2	Understand the algorithms of line generation, circle generation, transformation, curve, surface modelling and solid modelling
CO3	Understand the concept group technology, flexible manufacturing, Industry 4.0, robotics
CO4	Understand information material handling in CIM environment, rapid prototyping
CO5	Understand information system and material handling in CIM environment, rapid prototyping

Reference Books:

1. Mikell P. Groover - Automation , Production Systems and Computer Integrated Manufacturing, Second edition, Prentice Hall of India.
2. Ibrahim Zeid - CAD/CAM theory and Practice, Tata McGraw Hill Publishing Co. Ltd., Company Ltd., New Delhi.
3. Yoram Koren, Control of machine tools, McGraw-Hill.
4. Hearn & Baker, Computer Graphics, Prentice Hall of India
5. Sunil Kumar Srivastava, Computer Aided Design: A Basic and Mathematical Approach, I K International Publishing House
6. P. Radhakrishnan, - CAD/CAM/CIM, New Age International (P) Ltd., New Delhi

IME 064	Finite Element Methods	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	Introduction, exact solution vs approximate solution, principle of FEM, application of FEM, general procedure for finite element analysis, pre-processing, solution, post processing, Stresses and Equilibrium; Boundary Conditions.	8
II	Strain-Displacement Relations, Stress–strain relations, Effect of temperature, various approximate methods: weighted residual method, variational or Rayleigh Ritz method, Galerkin's method, principle of minimum potential energy	8
III	Basic element shapes, generalized co-ordinates, polynomials, natural co-ordinates in one-, two- and three-dimensions, Lagrange and Hermite polynomials, Application of Finite Element Methods to elasticity problems and heat conduction Problems	8
IV	One dimensional problem of finite element model, Coordinates and Shape function, Potential-energy approach, Galerkine approach, Assembly of Global Stiffness Matrix and Load Vector. Plane trusses: Global and local coordinate system and stress calculation. Beams and Frames: finite element formulation and calculation of Shear Force and Bending Moment.	8
V	Two-dimensional problem using Constant Strain Triangles and Four-node Quadrilateral, Problem modelling and Boundary conditions. Practical consideration in finite element applications, problem solving on a general-purpose FEM software package like ANSYS, ABAQUS, NISA etc.	8

Course Outcomes:

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

COs	Statements
CO1	Understand the basic concepts of FEM and its applications
CO2	Apply the procedure involved to solve a problem using Finite Element Methods
CO3	Develop the element stiffness matrices using different approach
CO4	Analyze 1D and 2D problem using different methods
CO5	Analyze the complex geometric problems through FEM software packages

Reference Books:

1. Chandrupatla, T. R. and Belegundu, A. K., Introduction to Finite Elements in Engineering, Pearson Education, India (2001).
2. Rao, S. S., Finite element method in engineering, 5th Edition, Pergaman Int. Library of Science, 2010.
3. Huebner, K. H., The Finite Element Method for Engineers, John Wiley, New York (2001).
4. Logan, D. L., A first course in the finite element method,6th Edition, Cengage Learning, 2016.

Open Elective Courses

IOE 066	Product Innovation & Entrepreneurship	3L:0T:0P	3 Credits

Unit	Topics	No. of Hours
I	**Entrepreneurship**: Role of entrepreneurship in economic development; Entrepreneurial mindset, motivation and competencies; Market pull and technology push factors; New product development lifecycle; Technology readiness levels; Product-market fit validation; Commercialization pathways; Business vision & leadership; Team composition & management.	8
II	**Product Innovation:** Opportunity scanning, market survey, need identification and problem definition; Creative design thinking for concept generation; Detailed design & prototyping; Functionality & manufacturability; Bill of materials & components supply chain; Manufacturing & assembly plan; Product testing & quality assurance; Intellectual property rights management.	8
III	**Marketing & Finance**: Market segmentation & market sizing; Customer persona & value proposition; Marketing (Go-to-market) strategy; Distribution channels and sales network; Funding requirement (based on stage); Source of funding for startup ventures; Financial projections and accounting; Startup to scale up financing.	8
IV	**Venture Creation**: Sustainable business options & pathways; Business model & business canvas; Startup team & business partners; Startup ecosystem and stakeholders; Technology business incubators & parks; Proposal pitching & agreements; Startup company incorporation; Social impact & responsibility.	8
V	**Course Project**: Need identification, innovative solution, business plan, go-to-market strategy.	8

Course Outcomes:

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

COs	Statements
CO1	Understand how to identify an unmet need through market research
CO2	Learn how to create an innovative solution and check problem-solution fit
CO3	Practice business planning, including marketing, fund-raising and start-up incubation.
CO4	Understanding of venture creation for incubated and start-up company
CO5	Application of Innovation & Entrepreneurship for market strategy

Reference Books:

1. Bill Aulet, “Technology Entrepreneurship”, 4th ed., Tata McGraw Hill, 2014.
2. Peter F. Drucker, “Innovation and Entrepreneurship”, 1st ed., Harper Business, 2006.
3. Chelat Bhuvanachandran, Innovision, Khanna Book Publishing, 2022.
4. Byers, Dorf, and Nelson, Technology Ventures: From Ideas to Enterprise, McGraw Hill, 2010
5. Steve Blank, “The Startup Owner's Manual”
6. T.V. Rao, “Entrepreneurship - A South Asian Perspective”