Curriculum for Undergraduate Degree (B.Tech.) in Mechanical Engineering (w.e.f. AY: 2020-21)

Part III: Detailed Curriculum

Seventh Semester

Course Name:	**Advanced Manufacturing Technology**		
Course Code:	PC-ME 701	**Category:**	Professional Core
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Manufacturing Processes, Manufacturing Technology
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	To introduce principles of material removal mechanism of advanced machining processes such as mechanical, electro-chemical and thermal.
2	To give basic understanding of the machining capabilities, limitations, and productivity of advanced manufacturing technologies.

Course Contents:

Module No.	Description of Topic/ Experiment	Contact Hrs.
1	**Module 1:** Mechanical Advanced Machining Processes – Need and classification of non-traditional machining processes, Material removal in traditional and non-traditional machining processes - considerations in process selection. Ultrasonic machining – Working principle, mechanism of metal removal – Theory of Shaw, elements of the processes, tool feed mechanism, effect of parameters, applications and numerical. Abrasive jet machining, Water jet machining and abrasive water jet machine - Basic principles, equipments, process variables, mechanics of metal removal, MRR, application and limitations.	6L
2	**Module-2:** Principle of ECM processes, chemistry of the ECM processes, Parameters of the process, determination of the metal removal rate,	6L

	dynamics of ECM process, polarization, tool design, advantages and disadvantages, application, electrochemical grinding, electrochemical honing, electrochemical deburring, Application of ECM for deep hole drilling - electrostream drilling and shaped tube electrolytic machining. Chemical machining - Fundamental principle, types of chemical machining, maskants, etchants, advantages, disadvantages, applications	
3	**Module-3:** Working principle of EDM, power circuits for EDM - RC pulse generator and controlled pulse generator– Analysis of R-C Circuits – Mechanics of metal removal in EDM, Process parameters, selection of tool electrode and dielectric fluids, surface finish and machining accuracy, characteristics of spark eroded surface and recent development in EDM. Wire EDM – Working principle, process variables, process characteristics and applications. Electric discharge grinding and electric discharge diamond grinding - working principle, process capabilities and applications.	6L
4	**Module-4:** Laser, Electron Beam, Ion Beam and Plasma Arc Machining: General working principle of laser beam machining – Generation of Laser, types of Lasers, process characteristics and applications. Electron Beam Machining - Equipment for production of Electron Beam, theory of EBM, thermal and non-thermal type, process characteristics and applications. Ion Beam Machining - Mechanism of metal removal and associated equipments, process characteristics and applications. Plasma Arc Machining - Metal removal mechanism, process parameters, process characteristics, types of torches, applications.	6L
5	**Module-5:** Advanced Finishing Processes: Abrasive flow Machining (AFM)- working principle, AFM system, process variables, process performance and applications. Magnetic abrasive finishing (MAF)- working principle, MAF system, material removal and surface finish, process variables and applications. Chemo-mechanical polishing, working principle, material removal and surface finish and applications.	6L
6	**Module-6:** Micro-Machining: Need- evolution- fundamentals and trends in micro technologies- Consequences of the technology and society- challenges to manufacturing technology- evolution of precision in manufacturing, tooling and current scenario, requirements and applications Theory of micromachining- Chip formation- Size effect in micromachining- micro turning- micro drilling.	6L
Total		**36L**

Course Outcomes:
After completion of the course, students will be able to:
1. To understand non- traditional machining processes and the effect of process parameters 2. To differentiate the various non-traditional machining processes 3. To demonstrate micromachining technology

Learning Resources:	
1	A. Ghosh and A.K. Mallik, Manufacturing Science, Affiliated East west Press Ltd, 2001.
2	V.K. Jain, Advanced Machining Processes, Allied Publishers Pvt. Ltd. 2002
3	H. El-Hofy, Advanced Machining Processes, McGraw-Hill, New York, 2005.
4	G.F. Benedict, Nontraditional Machining Processes, Marcel Dekker Inc., New York, 1987.
5	J.A. McGeough, Advanced Machining Methods, Chapman and Hakk, London, 1988.
6	M. Adithan, Modern Machining Methods, Khanna Publishers, New Delhi, 2008.

Course Name:	**Economics for Engineers**		
Course Code:	HU-HM 701	**Category:**	Professional Core
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Basic knowledge of Engineering Mechanics
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	To make general awareness among budding engineers regarding basic principles of economics
2	To give basic understanding of engineering costs, estimation, depreciation analysis and basic accounting principles.

Course Contents:		
Module No.	**Description of Topic/ Experiment**	**Contact Hrs.**
1	**Module 1:** Economic Decisions Making- Overview, Problems, Role, Decision making process.	2L
2	**Module 2:** Engineering Costs & Estimation- Fixed, Variable, Marginal & Average	4L

	Costs, Sunk Costs, Opportunity Costs, Recurring and Nonrecurring Costs, Incremental Costs, Cash Costs vs Book Costs, Life-Cycle Costs; Types of Estimate, Estimating Models - Per- Unit Model, Segmenting Model, Cost Indexes, Power- Sizing Model, Improvement & Learning Curve, Benefits.	
3	**Module 3:** Present Worth Analysis: End-of-Year Convention, Viewpoint of Economic Analysis Studies, Borrowed Money Viewpoint, Effect of Inflation & Deflation, Taxes, Economic Criteria, Applying Present Worth Techniques, Multiple Alternatives.	4L
4	**Module 4:** Cash Flow & Rate of Return Analysis- Calculations, Treatment of Salvage Value, Annual Cash Flow Analysis, Analysis Periods; Internal Rate of Return, Calculating Rate of Return, Incremental Analysis; Best Alternative Choosing an Analysis Method, Future Worth Analysis, Benefit-Cost Ratio Analysis, Sensitivity and Break Even Analysis. Economic Analysis in the Public Sector- Quantifying and Valuing Benefits & drawbacks.	4L
5	**Module 5: Enzymes:** Depreciation- Basic Aspects, Deterioration & Obsolescence, Depreciation and Expenses, Types of Property, Depreciation Calculation Fundamentals, Depreciation and Capital Allowance Methods, Straight-Line Depreciation Declining Balance Depreciation, Common Elements of Tax Regulations For Depreciation and Capital Allowances.	4L
6	**Module 6:** Inflation and Price Change- Definition, Effects, Causes, Price Change with Indexes, Types of Index, Composite vs Commodity Indexes, Use of Price Indexes in Engineering Economic Analysis, Cash Flows that inflate at different Rates.	3L
7	**Module 7:** Accounting- Function, Balance Sheet, Income Statement, Financial Ratios Capital Transactions, Cost Accounting, Direct and Indirect Costs, Indirect Cost Allocation.	3L
Total		**24L**

Course Outcomes:	
After completion of the course, students will be able to:	
1	To understand Economic Decisions Making criteria
2	To know basic principles of engineering costs, estimation and depreciation analysis.
3	To understand basic accounting principles.

Learning Resources:	
1	Premvir Kapoor, Sociology & Economics for Engineers, Khanna Publishing House, Delhi.
2	J.L. Riggs, D.D. Bedworth and S.U. Randhawa, Engineering Economics, 4th Edition, McGraw Hill International Edition, 1996.
3	D. Newnan, T. Eschembach and J. Lavelle, Engineering Economics Analysis, Oxford University Press, 2019.
4	J.A. White, K.E. Case and D.B. Pratt, Principle of Engineering Economic Analysis, John Wiley, 2016.

Course Name:	**Mechanical Engineering Laboratory III (Manufacturing)**		
Course Code:	PC-ME 791	**Category:**	Professional Core Courses
Semester:	Seventh	**Credit:**	1.5
L-T-P:	0-0-3	**Pre-Requisites:**	Manufacturing Processes, Manufacturing Technology
Full Marks:	100		
Examination Scheme:	Semester Examination: 60	Continuous Assessment: 40	Attendance: 0

Course Objectives:	
1	To understand the kinematics and rigid- body dynamics of kinematically driven machine components.
2	To understand the motion of linked mechanisms in terms of the displacement, velocity and acceleration at any point in a rigid link.
3	To be able to design some linkage mechanisms and cam systems to generate specified output motion.
4	To understand the kinematics of gear trains.

Course Contents:

Module No.	**Description of Topic/ Experiment**	**Contact Hrs.**
1	Measurement of Cutting Force in Turning	3L
2	Study of the effect of parametric variation in arc welding	3L
3	Testing of moulding sand	3L
4	Testing for Weld Quality	3L
5	Study of and Solving problems on geometry of robot manipulator, actuators and grippers	3L
6	Programming on CNC Lathe using G and M Codes	3L
7	Programming on CNC Lathe using APT	3L
8	Programming on CNC Milling Machine using G and M Codes	3L

9	Programming on CNC Milling Machine using APT	3L
10	Programming on CNC machine Simulator and to observe virtual machining	3L
11	Robot Programming	3L
12	Experiments on AJM/ USM/ WEDM/ EDM/ ECM/ LBM	3L
13	Design and manufacture of products using Additive Manufacturing	3L
	*Minimum 12 experiments needs to be performed	
Total		**36L**

Course Outcomes:
After completion of the course, students will be able to:
1. Study cutting forces in machining processes 2. Test the quality of weld and moulding sands 3. Develop a practical understanding of advanced manufacturing processes. 4. Understand the working of a robot and its programming 5. Identify and rectify defects in parts and manufacturing processes related problems.

Learning Resources:	
1	M.P. Groover, Principles of Modern Manufacturing, 5th edition, Wiley, 2014.
2	E.P. DeGarmo, J.T. Black and R.A. Kohser, DeGarmo's Materials and Processes in Manufacturing, 11th Edition, John Wiley & Sons, 2011.
3	S. Kalpakjian and Schmid, Manufacturing processes for engineering materials, 5th edition, Pearson Education, 2010.

Course Name:	**Project III**		
Course Code:	PW-ME 781	**Category:**	Project/Sessional
Semester:	Fifth	**Credit:**	3
L-T-P:	0-0-6	**Pre-Requisites:**	Nil
Full Marks:	100		
Examination Scheme:	Semester Examination: 100 (Viva-voce)	Continuous Assessment: 00	Attendance: 00

Course Objectives:	
1	To develop the ability to identify, formulate and analyze engineering problems through literature survey, recent trends in industries and by applying the knowledge of science and engineering fundamentals.
2	To train students in preparing project reports, to face reviews and viva voce examination.

Course Contents:
Description of Topic/ Experiment
It is intended to start the project work early in the seventh semester and carry out both design and fabrication of a mechanical device whose working can be demonstrated. The design and formulation of the problem is expected to be completed in the seventh semester and the fabrication and demonstration will be carried out in the eighth semester. The students in a group of 4 to 6 works on a topic are to be approved by the head of the department under the guidance of a faculty member. The students prepare a comprehensive project report after completing the work to the satisfaction of the supervisor to be submitted at the end of the semester. The progress of the project is evaluated by a committee may be constituted by the Head of the Department. The project work is evaluated based on oral presentation and the project report may jointly by external and internal examiners constituted by the Head of the Department.

Course Outcomes:
After completion of the course, students will be able to:
1. Carry out some project works based on some design or fabrication or 2. Analyse experimental problems in a group building up team spirit and would get sufficient exposure for 3. Find out the way to proceed to solve a practical or design problem.

Course Name:	**Automobile Engineering**		
Course Code:	A	**Category:**	Professional elective courses
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Thermodynamics, Kinematics & Theory of Machines
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	To impart knowledge on various types of power-driven vehicles and to familiarize the students with the fundamentals of Automotive Engine System, Chassis and suspension system, braking and transmission system, and cooling system.

Course Contents:		
Module No.	**Description of Topic/ Experiment**	**Contact Hrs.**
1	**Module 1:** Introduction: History & Development of Automobile. Various sub systems of Automobile.	1L
2	**Module 2:** Prime Mover: Engine for Two-Wheeler & Three-Wheeler vehicles, Engine for passenger cars, commercial and other vehicle, Fuel system for carburetted engine, MPFI engine and Diesel engine, Lubrication and cooling system.	5L
3	**Module 3:** Auto Electrical: Electric Motor as prime mover, Battery, generator, Ignition system, starting system, lighting & signalling.	6L
4	**Module 4:** Steering System: Devis steering & Ackerman steering system. Rack & pinion, cam & lever, worm & sector system.	3L
5	**Module 5:** Transmission System: Flywheel & clutch. Gearbox sliding and constant mesh type, Automatic Transmission, Universal joint, Propeller shaft.	6L
6	**Module 6:** Differential & Axle: Construction & function of differential, Different types of front & rear axles.	3L
7	**Module 7:** Suspension System: Conventional and independent suspension system, application.	3L
8	**Module 8:** Brake System: Disc & drum brake, Hydraulic brake, Parking brake. Stopping distance.	3L
9	**Module 9:** Power Requirement: Various resistances such as air resistance, gradient resistance, rolling resistance. Tractive effort. Torque- Speed curve. Horse power calculation	3L
10	**Module 10:** Automotive air conditioning: Ventilation, heating, air condition, refrigerant, compressor and evaporator. Wheels and tyres: Wheel quality, assembly, types of wheels, wheel rims. Construction of tyres and tyre specifications. Automotive Restraint Systems: Seat belt, automatic seat belt tightener system, collapsible steering column and air bags.	3L
Total		**36L**

Course Outcomes:
After completion of the course, students will be able to:
1. Understand the basic lay-out of an automobile. 2. Explain the operation of engine cooling, lubrication, ignition, electrical and air conditioning systems. 3. Illustrate the principles of transmission, suspension, steering and braking systems. 4. Demonstrate automotive electronics. 5. Study latest developments in automobiles.

Learning Resources:	
1	K. Newton, W. Steed and T.K. Garrette, Motor Vehicle, 2nd Edition, Butterworth, 1989.
2	A.K. Babu, Automobile Mechanics, Khanna Publishing House, 2019.
3	A. De, Automobile Engineering, Revised Edition, Galgotia Publication Pvt. Ltd., 2010.
4	W.H. Crouse and D.L. Anglin, Automotive Mechanics, McGraw Hill, New Delhi, 2005.
5	J. Heitner, Automotive Mechanics, Affiliated South West Press, New Delhi, 2000.

Course Name:	**Computational Fluid Dynamics**		
Course Code:	B	**Category:**	Professional elective courses
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Thermodynamics, Heat transfer and Fluid Mechanics
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	The objective of the course is to impart knowledge on numerical modeling and its role for the solution of complex engineering problems in the field of heat transfer and fluid dynamics.

Course Contents:

Module No.	Description of Topic/ Experiment	Contact Hrs.
1	**Module 1:** Introduction: History and Philosophy of computational fluid dynamics, CFD as a design and research tool, Applications of CFD in engineering, Programming fundamentals, MATLAB programming, Numerical	2L

	Methods	
2	**Module 2:** Governing equations of fluid dynamics: Models of the flow, The substantial derivative, Physical meaning of the divergence of velocity, The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.	4L
3	**Module 3:** Mathematical behavior of partial differential equations: Classification of quasi-linear partial differential equations, Methods of determining the classification, General behavior of Hyperbolic, Parabolic and Elliptic equations.	2L
4	**Module 4:** Basic aspects of discretization: Introduction to finite differences, Finite difference equations using Taylor series expansion and polynomials, Explicit and implicit approaches, Uniform and unequally spaced grid points.	3L
5	**Module 5:** Grids with appropriate transformation: General transformation of the equations, Metrics and Jacobians, the transformed governing equations of the CFD, Boundary fitted coordinate systems, Algebraic and elliptic grid generation techniques, Adaptive grids.	4L
6	**Module 6:** Parabolic partial differential equations: Finite difference formulations, Explicit methods - FTCS, Richardson and DuFort-Frankel methods, Implicit methods - Lasonen, Crank-Nicolson and Beta formulation methods, Approximate factorization, Fractional step methods, Consistency analysis, Linearization.	4L
7	**Module 7:** Stability analysis: Discrete Perturbation Stability analysis, von-Neumann Stability analysis, Error analysis, Modified equations, Artificial dissipation and dispersion.	3L
8	**Module 8:** Scalar representation of Navier-Stokes equations: Equations of fluid motion, numerical algorithms: FTCS explicit, FTBCS explicit, Dufort-Frankel explicit, McCormack explicit and implicit, BTCS and BTBCS implicit algorithms, applications.	4L
9	**Module 9:** Grid generation: Algebraic Grid Generation, Elliptic Grid Generation, Hyperbolic Grid Generation, Parabolic Grid Generation	3L

10	**Module 10:** Finite volume method for unstructured grids: Advantages, Cell Centered and Nodal point Approaches, Solution of Generic Equation with tetrahedral Elements, 2-D Heat conduction with Triangular Elements.	3L
11	**Module 11:** CFD Solution Procedure: Problem setup – creation of geometry, mesh generation, selection of physics and fluid properties, initialization, solution control and convergence monitoring, results reports and visualization. Case Studies: Benchmarking, validation, Simulation of CFD problems by use of general CFD software, Simulation of coupled heat, mass and momentum transfer problem.	4L
Total		**36L**

Course Outcomes:
After completion of the course, students will be able to:
1. Understand the differential equations for flow phenomena and numerical methods for their solution. 2. Analyze different mathematical models and computational methods for fluid flow and heat transfer simulations. 3. Formulate computational problems related to fluid flows and heat transfer. 4. Estimate the accuracy of a numerical solution by comparison to known solutions of simple test problems and by mesh refinement studies. 5. Evaluate forces in both internal and external flows.

Learning Resources:	
1	P. S. Ghosdastidar, Computer Simulation of Flow and Heat Transfer, McGraw-Hill, 1998.
2	K. Muralidhar and T. Sundararajan, Computational Fluid Flow and Heat Transfer, Narosa Publishing House, 1995.
3	J. D. Anderson Jr., Computational Fluid Dynamics, McGraw-Hill Book Company, 1995.
4	P. Niyogi, S. K. Chakrabarty and M.K. Laha, Introduction to Computational Fluid Dynamics, Pearson Education, 2006.

Course Name:	**Non-Conventional Energy Sources**		
Course Code:	C	**Category:**	Professional elective courses
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Thermodynamics, Heat transfer
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	The objective of the course is to impart knowledge on numerical modeling and its role for the solution of complex engineering problems in the field of heat transfer and fluid dynamics.

Course Contents:		
Module No.	**Description of Topic/ Experiment**	**Contact Hrs.**
1	**Module 1:** Introduction: Energy source, India's production and reserves of commercial energy sources, need for nonconventional energy sources, energy alternatives, solar, thermal, photovoltaic. Water power, wind biomass, ocean temperature difference, tidal and waves, geothermal, tar sands and oil shale, nuclear (Brief descriptions); advantages and disadvantages, comparison (Qualitative and Quantitative).	2L
2	**Module 2:** Solar Radiation: Extra-Terrestrial radiation, spectral distribution of extra-terrestrial radiation, solar constant, solar radiation at the earth's surface, beam, diffuse and global radiation, solar radiation data. Solar Radiation Geometry: Flux on a plane surface, latitude, declination angle, surface azimuth angle, hour angle, zenith angle, solar altitude angle expression for the angle between the incident beam and the normal to a plane surface (No derivation) local apparent time. Apparent motion of sum, day length, numerical examples. Solar Thermal Conversion: Collection and storage, thermal collection devices, liquid flat plate collectors, solar air heaters concentrating collectors (cylindrical, parabolic, paraboloid) (Quantitative analysis); sensible heat storage, latent heat storage, application of solar energy water heating. Space heating and cooling, active and passive systems, power generation, refrigeration. Distillation (Qualitative analysis) solar	10L

	pond.	
3	**Module 3:** Wind Energy: Properties of wind, availability of wind energy in India, wind velocity and power from wind; major problems associated with wind power, wind machines; Types of wind machines and their characteristics, horizontal and vertical axis wind mills, elementary design principles; coefficient of performance of a wind mill rotor, aerodynamic considerations of wind mill design, numerical examples.	4L
4	**Module 4:** Tidal Power: Tides and waves as energy suppliers and their mechanics; fundamental characteristics of tidal power, harnessing tidal energy, limitations.	4L
5	**Module 5:** Ocean Thermal Energy Conversion: Principle of working, Rankine cycle, OTEC power stations in the world, problems associated with OTEC.	4L
6	**Module 6:** Geothermal Energy Conversion: Principle of working, types of geothermal station with schematic diagram, geothermal plants in the world, problems associated with geothermal conversion, scope of geothermal energy.	4L
7	**Module 7:** Energy from Biomass: Photosynthesis, photosynthetic oxygen production, energy plantation, bio gas production from organic wastes by anaerobic fermentation, description of bio-gas plants, transportation of bio-gas, problems involved with bio-gas production, application of bio-gas, application of bio-gas in engines, advantages.	4L
8	**Module 8:** Hydrogen Energy: Properties of Hydrogen with respected to its utilization as a renewable form of energy, sources of hydrogen, production of hydrogen, electrolysis of water, thermal decomposition of water, thermo chemical production bio-chemical production	4L
Total		**36L**

Course Outcomes:
After completion of the course, students will be able to:
1. Describe the environmental aspects of non-conventional energy resources. In Comparison with various conventional energy systems, their prospects and limitations. 2. Know the need of renewable energy resources, historical and latest developments. 3. Describe the use of solar energy and the various components used in the energy production with respect to applications like-heating, cooling, desalination, power generation, drying, cooking etc.

4. Appreciate the need of Wind Energy and the various components used in energy generation and know the classifications. 5. Understand the concept of Biomass energy resources and their classification, types of biogas Plants- applications 6. Compare Solar, Wind and bio energy systems, their prospects, Advantages and limitations.

Learning Resources:	
1	G.D. Rai, 'Non Conventional Energy Sources', Khanna Publishers, New Delhi.
2	G. N. Tiwari and M. K. Ghoshal, Renewable Energy Sources Basic Principles and Applications, Narosa Publishing House, New Delhi.
3	John Twidell , Tony Weir , 'Renewable Energy Resources', Taylor & Francis; 2nd edition, 2005

Course Name:	**Finite Element Analysis**		
Course Code:	D	**Category:**	Professional elective courses
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Design, Applied Mathematics, Numerical Methods
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	To apprise the students about the basics of the Finite Element analysis technique, a numerical tool for the solution of different classes of problems in solid mechanics, thermal engineering, and fluid mechanics.

Course Contents:		
Module No.	**Description of Topic/ Experiment**	**Contact Hrs.**
1	**Module 1:** Introduction: Historical background, Relevance of FEA/FEM to design problems, Application to the continuum– Discretization, Matrix approach, Matrix algebra– Gaussian elimination, Governing equations for continuum, Classical Techniques in FEM, Weighted residual method, Ritz method, Galerkin method	6L
2	**Module 2:** One dimensional problems: Finite element modeling– Coordinates and	6L

	shape functions, Potential energy approach– Element matrices and vectors, Assembly for global equations, Boundary conditions, Higher order elements- Shapes functions, Applications to axial loadings of rods– Extension to plane trusses, Bending of beams– Finite element formulation of stiffness matrix and load vectors, Assembly to Global equations, boundary conditions, Solutions and Post processing, Example Problems.	
3	**Module 3:** Two dimensional problems: scalar variable problems: Finite element modeling– CST element, Element equations, Load vectors and boundary conditions, Assembly, Application to heat transfer, Examples	3L
4	**Module 4:** Two dimensional problems: vector variable problems: Vector Variable problems, Elasticity equations–Plane Stress, Plane Strain and Axisymmetric problems, Formulation, element matrices, Assembly, boundary conditions and solutions Examples	7L
5	**Module 5:** Isoparametric elements for two dimensional problems: Natural coordinates, Isoparametric elements, Four node quadrilateral element, Shape functions, Element stiffness matrix and force vector, Numerical integration, Stiffness integration, Displacement and Stress calculations, Examples.	6L
6	**Module 6:** Numerical Integration and 2-D problems of Elasticity: Introduction to numerical integration, two dimensional integrals, plane stress, plane strain, axisymmetric, plate bending problems. Thermal Applications: Two- dimensional heat conduction analysis, formulation of functional, element matrices and case studies. Fluid Mechanics Applications: Stream function formulation, velocity potential formulation and torsional analysis of a prismatic bar. Computer implementation: Pre-processor, Processor, Postprocessor. Discussion about finite element packages.	8L
Total		**36L**

Course Outcomes:
After completion of the course, students will be able to: 1. Apply finite element method to solve problems in solid mechanics and heat transfer. 2. Formulate and solve problems in one dimensional structures including trusses, beams and frames. 3. Formulate FE characteristic equations for two dimensional elements and analyse plain stress, plain strain, and axi-symmetric and plate bending problems. 4. To learn and apply finite element solutions to structural, thermal, fluid mechanics problem

5. To develop the knowledge and skills needed to effectively evaluate finite element analyses

Learning Resources:	
1	P. Seshu, Textbook of Finite Element Analysis, Prentice Hall of India, 2009.
2	J. N. Reddy, Finite Element Method in Engineering, McGraw Hill, 2009.
3	O.C. Zienkiewicz, R.L. Taylor and J.Z. Zhu, The Finite Element Method for Solid and Structural Mechanics, 4th Edition, Elsevier 2007.
4	R.D. Cook, D.S. Malkus and M.E. Plesha, Concepts and Applications of Finite Element Analysis, Wiley, 2001.

Course Name:	**CAD/CAM**		
Course Code:	E	**Category:**	Professional elective courses
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Manufacturing Technology, Elements of Mechanical Design, Mathematics
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	To impart knowledge about computer aided design- geometric modeling, stress analysis.
2	To give an idea about computer aided manufacturing system, its components including application of robot.

Course Contents:		
Module No.	**Description of Topic/ Experiment**	**Contact Hrs.**
1	**Module 1:** Fundamentals of CAD- Design process, benefits of computer aided design, graphics standards.	3L
2	**Module 2:** Geometric modeling- wire-frame, surface and solid modelling Transformation- translation and rotation exercise problems and programming. Stress analysis- basics of FEM, formation of stiffness matrix for two elements.	6L
3	**Module 3:**	4L

	Introduction to computer aided manufacturing (CAM) systems, basic building blocks of computer integrated manufacturing (CIM).	
4	**Module 4:** Toolings of CNC machines, tool and work handling systems involving robot, AGV, RTV, AS/RS, ATC, APC.	3L
5	**Module 5:** Robotics; types, anatomy, drives and applications.	3L
6	**Module 6:** Computer aided production planning and control, Manufacturing from product design- CADCAM interface, concept of group technology (GT), CAPP.	6L
7	**Module 7:** Control systems, Process monitoring, Adaptive control systems etc.	2L
8	**Module 8:** Automatic inspection systems, use of CMM, Reverse Engineering.	1L
Total		**28L**

Course Outcomes:
After completion of the course, students will be able to: 1. To familiarize the basics of computer aided design- geometric modeling, stress analysis. 2. To familiarize the basics of computer aided manufacturing. 3. To familiarize the components of computer aided manufacturing system including application of robot and control systems.

Learning Resources:	
1	P.N. Rao, N.K. Tewari and T.K. Kundra, Computer Aided Manufacturing, McGraw-Hill Publication, 2017.
2	P.N. Rao, CAD/CAM, McGraw Hill Publication, 2010.
3	M.P. Groover and E.W. Zimmers Jr., CAD/CAM, Prentice Hall of India, 1983.
4	P. Radhakrishnan, S. Subramanyan and V. Raju, CAD/CAM/CIM, New Age International Publishers, 2007.
5	M.P. Groover, Automation, Production Systems, and Computer- Integrated Manufacturing, Prentice Hall of India, 2016.

Course Name:	**Advanced Welding Technology**		
Course Code:	F	**Category:**	Professional elective courses
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Manufacturing Processes
Full Marks:	100		

Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	To impart knowledge about different welding processes and their applicability.
2	To make the students understand the mechanism behind weld joints.
3	To impart ideas of different testing techniques of the welded joint.

Course Contents:

Module No.	Description of Topic/ Experiment	Contact Hrs.
1	**Module 1:** Review of welding processes, joint design.	3L
2	**Module 2:** Descriptions and Parametric influences on Welding processes: Arc Welding- SMAW, Stud Arc welding, SAW, GMAW, GMAW-P, FCAW, GTAW, GTAW-P. Resistance Welding processes- Spot, Butt, Seam, Projection. Solid State Welding processes- Forge welding, Friction welding, Friction Stir welding, Diffusion welding, Roll welding.	6L
3	**Module 3:** Arc Welding- Different types of equipment, Power sources, Choice of Polarity, Arc characteristics, Modes of Metal Transfer, Welding Positions, Electrode selection.	5L
4	**Module 4:** Critical and Precision Welding processes- USW, PAW, LBW, EBW. Underwater Welding- Wet Welding and Dry Welding: Hyperberic and Cavity. Welding of Plastics- Hot Gas Welding, Hot Tool Welding, Hot Press Welding, Friction Welding, Ultrasonic Welding. Joining of Ceramics and Composites.	8L
5	**Module 5:** Welding Metallurgy, HAZ, Effect of different process parameters on the characteristics of weldment. Weldability of Plain Carbon Steel, Stainless Steel, Cast Iron, Aluminium and its Alloys.	8L
6	**Module 6:** Welding Defects- Types, Causes, Inspection and Remedial Measures. Testing of Welded Joints- Visual Inspection, Dye-Penetration (DP) Test, Ultrasonic Test and Radiography Test.	3L
7	**Module 7:** Welding Fixtures, Welding Automation and Robotic Welding. Safe Practices in Welding.	3L
Total		**36L**

Course Outcomes:
After completion of the course, students will be able to: 1. To familiarize different types of welding processes. 2. To familiarize the basic mechanism behind weld joint and influencing factors. 3. To impart the knowledge different tests to judge soundness of the weld joint.

Learning Resources:	
1	O.P. Khanna, A Text Book of Welding Technology, Dhanpat Rai & Sons, 2015.
2	R.S. Parmar, Welding Engineering and Technology, Khanna Publishers, 2013.
3	M. Bhattacharyya, Weldment Design, The Association of Engineers, India Publication, Kolkata, 1991.
4	H. Udin, E.R. Funk and J. Wulf, Welding for Engineers, John Wiley and Sons, 1954.

Course Name:	**Additive Manufacturing**		
Course Code:	G	**Category:**	Professional elective courses
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Manufacturing Processes
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	To introduce students the basics of additive manufacturing/rapid prototyping and its applications in various fields, reverse engineering techniques.
2	To familiarize students with different processes in rapid prototyping systems.
3	To teach students about mechanical properties and geometric issues relating to specific rapid prototyping applications.

Course Contents:		
Module No.	**Description of Topic/ Experiment**	**Contact Hrs.**
1	**Module 1:** Definition , Generic Additive Manufacturing (AM) Process, Terms related to AM, Benefits of AM, Distinction between AM and CNC machining, Additive manufacturing process chain: Variation between different AM machines, Metal systems, Maintenance of Equipment, Material Handling Issues.	8L

2	**Module 2:** Introduction to rapid prototyping (RP), Need of RP in context of batch production, Basic principles of RP, Steps in RP, Process chain in RP in integrated CAD- CAM environment, Advantages of RP, Medical applications.	6L
3	**Module 3:** Classification of different RP techniques – based on raw materials, layering technique (2-D or 3-D) and energy sources: Process technology, Stereo-lithography (SL), photo polymerization, liquid thermal polymerization, Solid foil polymerization.	8L
4	**Module 4:** Selective laser sintering, Selective powder binding, ballistic particle manufacturing – both 2D and 3-D, Fused deposition modeling, Shape melting, Laminated object manufacturing, Solid ground curing, 3-D printing.	8L
5	**Module 5:** Introduction to Reverse Engineering: Meaning, Use, RE-The generic process, Phase of RE–scanning, Contact Scanners, Noncontact Scanners, Point Processing, Application Geometric Model, Development.	6L
Total		**36L**

Course Outcomes:

After completion of the course, students will be able to:

1. Demonstrate the knowledge of Additive Manufacturing and Rapid Prototyping technologies.
2. Describe different RP techniques.
3. know fundamentals of Reverse Engineering.

Learning Resources:

1	Ian Gibson, David W. Rosen, Brent Stucker , “Additive Manufacturing Technologies” , Springer, 2009.
2	Chua C. K., Leong K. F., and Lim C. S., “Rapid Prototyping: Principles and Applications”, Second Edition, World Scientific Publishers (2003).
3	Patri K. Venuvinod, Weiyin Ma “Rapid Prototyping: Laser-Based and Other Technologies” Springer , 2004

Course Name:	**Industrial Engineering**		
Course Code:	A	**Category:**	Open elective courses
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Basic knowledge on engineering
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	To provide introductory knowledge on Industrial Engineering, concept of Productivity and work study.
2	To make familiar about facility layout and planning, systems of production planning and control and technics of inventory management.

Course Contents:

Module No.	Description of Topic/ Experiment	Contact Hrs.
1	**Module 1:** Introduction to Industrial Engineering and Productivity: Definition and Functions of Industrial Engineering, Origin and development of factory system, Contribution of Taylor and Gilbreth Productivity: Definition of productivity, Factors Influencing Productivity, Causes of Low Productivity, Productivity Measurement Models, Productivity Improvement Techniques.	3L
2	**Module 2:** Work Study: Basic Concept, Steps Involved in Work Study, Techniques of Work Study, Human Factors in the Application of Work Study. Method Study: Basic Concept, Steps Involved in Method Study, Recording Techniques, Operation Process Charts, Flow Process Charts, Two-Handed-Process Charts, Multiple Activity Charts, Flow Diagrams. String Diagrams, Principles of Motion Economy, Micro-Motion Study, Therbligs, SIMO Charts. Work Measurement: Basic Concept, Techniques of Work Measurement, Steps Involved in Time Study, Time Study Equipment, Performance Rating, Basic concept and Procedure of Work Sampling Study.	10L
3	**Module 3:** Facility Layout and Planning: Nature, Significance and Scope of Facility layout and design; Steps in facility layout planning, Assembly Line Balancing. Material Handling: Definition, Objective and Principles of Material	10L

	Handling, Classification of Material Handling Devices.	
4	**Module 4:** Production Planning and Control: Introduction to Production Systems, Types of production systems, Need and functions of PPC. Forecasting: Definition and Functions of Forecasting, Forecasting techniques: linear regression, moving average, exponential smoothing; Analysis of forecast error. Aggregate production planning, Capacity Planning, ERP, Master Production Schedule. Basic sequencing and scheduling techniques.	4L
5	**Module 5:** Introduction to Inventory Management: Importance and areas of materials management, Introduction to Inventory: Definitions, Need for inventory, Types of inventory, Inventory costs; Structure of inventory models, Deterministic models; safety stock, inventory control systems; Selective inventory management. MRP and JIT-based production systems, Concept of zero inventory, Fundamental concepts of purchasing, storing, distribution, and value analysis & engineering.	9L
Total		**36L**

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

Learning Resources:	
1	S. C. Sharma, Industrial Engineering and Management, Khanna Book Publication, 2016.
2	O. P. Khanna, Industrial Engineering and Management, Dhanpat Rai Publication, 1980.
3	M. T. Telsang, Industrial Engineering and Production Management, S. Chand Publishing, 2018.
4	K. B. Zandin and H. B. Maynard, Maynard's Industrial Engineering Hand Book, McGraw Hill Education, 2001.
5	B. Mahadevan, Operations Management: Theory and Practice, Pearson, 2010.

Course Name:	**Computational Methods in Engineering**		
Course Code:	B	**Category:**	Open elective courses
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Engineering Mathematics
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	To learn about different numerical techniques.
2	To learn about the application of numerical techniques in different fields of mechanical engineering.
3	To learn about different transformation techniques.
4	To understand concept of linear regression and statistical analysis.

Course Contents:

Module No.	Description of Topic/ Experiment	Contact Hrs.
1	**Module 1:** Approximations: Accuracy and precision, round off and truncation errors, error propagation.	3L
2	**Module 2:** Linear algebraic equations: Formulation and solution of linear algebraic equations, Gauss elimination, LU decomposition, iteration methods– convergence, Eigen values and Eigen vectors.	4L
3	**Module 3:** Interpolation methods: Newton's divided difference, interpolation polynomials, Lagrange interpolation polynomials.	5L
4	**Module 4:** Differentiation and Integration: High accuracy integration formula, extrapolation, derivatives of unequally spaced data, Gauss quadrature and integration.	5L
5	**Module 5:** Numerical solution of Algebraic equation: Bisection method, Regula-Falsi method, Newton-Raphson method.	4L
6	**Module 6:** Transform techniques: Continuous Fourier series, frequency and time domains, Laplace transform, Fourier integral and transform, Discrete Fourier Transform, fast Fourier Transform.	6L

7	**Module 7:** Differential Equations: Initial and boundary value problems, eigen value problems, solutions to elliptical and parabolic equations, partial differential equations.	5L
8	**Module 8:** Regression methods: Linear and non-linear regression, multiple linear regression, general linear test squares. Statistical methods: Statistical representation of data, modelling and analysis of data, ANOVA, test of hypotheses.	4L
Total		**36L**

Course Outcomes:
After completion of the course, students will be able to: 1. understand the concept of truncation and round off errors; fixed and floating point arithmetic and propagation of error and interpolation or extrapolation. 2. integrate different functions numerically and understand the error expressions. 3. solve systems of linear, algebraic and ordinary differential equations. 4. apply Laplace and Fourier transformation techniques. 5. use linear and non-linear regression techniques and do analysis of variance (ANOVA).

Learning Resources:	
1	S.K. Gupta, Numerical Methods for Engineers, New Age International, 2005.
2	S.C. Chapra and R.P. Canale, Numerical Methods for Engineers, McGraw Hill, 1989.
3	R.J. Schilling and S.L. Harris, Applied Numerical Methods for Engineering using MATLAB and C, Brooks/Cole Pub., 2000.
4	W.W. Hines and Montgomery, Probability and Statistics in Engineering and Management Studies, John Wiley,1990.

Course Name:	**Biomechanics and Biomaterials**		
Course Code:	C	**Category:**	Open elective courses
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Biology, Engineering Mathematics
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	To know musculoskeletal anatomy, dynamics to human motion and biomaterial

	interfaces.
2	To understand fundamentals of biomaterials science, physico-chemical properties of biomaterials and their testing techniques.

Course Contents:		
Module No.	**Description of Topic/ Experiment**	**Contact Hrs.**
1	**Module 1:** Musculoskeletal Anatomy: Basic Statics and Joint Mechanics (elbow, shoulder, spine, hip, knee, ankle)	6L
2	**Module 2:** Basic Dynamics to Human Motion: Review of linear and angular kinematics; Kinetic equations of motion; Work & energy methods; Momentum methods; Examples in biomechanics; Modern kinematic measurement techniques; Applications of human motion analysis Structure, Function, and Adaptation of Major Tissues and Organs.	6L
3	**Module 3:** Fundamental Strength of Materials in Biological Tissues: Introduction to Viscoelasticity. Fundamentals of biomaterials science. Concept of biocompatibility. Classes of biomaterials used in medicine, basic properties, medical requirements and clinical significance. Disinfection and sterilization of biomaterials.	6L
4	**Module 4:** Physico-Chemical Properties of Biomaterials: mechanical (elasticity, yield stress, ductility, toughness, strength, fatigue, hardness, wear resistance), tribological (friction, wear, lubricity), morphology and texture, physical (electrical, optical, magnetic, thermal), chemical and biological properties.	6L
5	**Module 5:** Elements in Contact with the Surface of a Biomaterial: Blood composition, plasma proteins, cells, tissues. Phenomena at the Biointerfaces. Molecular and cellular processes with living environment, blood-materials interaction, short and long term reactions to the body.	6L
6	**Module 6:** Testing of Biomaterials: in vitro, in vivo preclinical and in vivo clinical tests. Technologies of biomaterials processing, as implants and medical devices; improvement of materials biocompatibility by plasma processing.	6L
Total		**36L**

Course Outcomes:
After completion of the course, students will be able to: 1. Understand dynamics of human motion with the knowledge of musculoskeletal anatomy and biomaterial interfaces. 2. Understand fundamental characteristics and properties of biomaterials and their testing techniques.

Learning Resources:	
1	D.V. Knudson, Fundamentals of Biomechanics, Springer, 1999.
2	N. Ozkaya, M. Nordin, D. Goldsheyder and D. Leger, Fundamentals of Biomechanics: Equilibrium, Motion, and Deformation, Springer, 2012.
3	Y.C. Fung, Biomechanics: Mechanical Properties of Living Tissues, Springer, 1981.
4	M. Nordin and V.H. Frankel, Basic Biomechanics of the Musculoskeletal System, Barnes & Noble, 2011.
5	B.D. Ratner and A.S. Hoffman (Eds.), Biomaterials Science, An Intoduction to Materials in medicine, 3rd Edition, Academic Press, New York, 2012.

Course Name:	**Artificial Intelligence and Machine Learning**		
Course Code:	D	**Category:**	Open elective courses
Semester:	Seventh	**Credit:**	3
L-T-P:	3-0-0	**Pre-Requisites:**	Basic Engineering Mathematics and Programming Languages
Full Marks:	100		
Examination Scheme:	Semester Examination: 70	Continuous Assessment: 25	Attendance: 05

Course Objectives:	
1	This course will give an opportunity to gain expertise in one of the most fascinating and fastest growing areas of Computer Science through classroom program that covers fascinating and compelling topics related to human intelligence and its applications in industry, defence, healthcare, agriculture and many other areas. This course will give the students a rigorous, advanced and professional graduate-level foundation in Artificial Intelligence.

Course Contents:		
Module No.	**Description of Topic/ Experiment**	**Contact Hrs.**
1	**Module 1:** Introduction to AI: Introduction, The Turing Test Approach, Cognitive Modeling Approach, Laws of thought Approach, Rational agent Approach, AI Methods and tools, Foundations of Artificial Intelligence, Goals of AI, Performing Natural Language Processing using Email Filters in Gmail, Performing Natural Language Generation using Smart replies in Gmail.	6L
2	**Module 2:** Fundamentals of Machine Learning: Describing structural patterns, Machine Learning, Data Mining, Simple Examples, Fielded Examples, Machine Learning and statistics, Generalization as a search, Data mining and ethics. Data pre-processing using Weka, Handling high dimensional data through feature reduction in Weka.	6L
3	**Module 3:** Machine Learning Tasks: Decision Tables, Decision Trees, Classification rules, Association rules, Rules with exceptions, Rules involving relations, Trees for numeric prediction, Instance based representation, Clusters. Building soybean classification model using decision trees, generating association rules on weather data using Weka, Exploring Classification and Clustering techniques using scikit-learn or Weka.	6L
4	**Module 4:** Search Algorithms: Random search, Search with closed and open list, Depth first and Breadth first search, Heuristic search, Best first search, A* algorithm, Game Search.	6L
5	**Module 5:** Probabilistic Reasoning: Probability, conditional probability, Bayes Rule, Bayesian Networks- representation, construction and inference, temporal model, hidden Markov model.	6L
6	**Module 6:** Markov Decision process: MDP formulation, utility theory, utility functions, value iteration, policy iteration and partially observable MDPs.	6L
Total		**36L**

Course Outcomes:
After completion of the course, students will be able to: 1. Build intelligent agents for search and games.

2. Solve AI problems through programming with Python. 3. Learning optimization and inference algorithms for model learning. 4. Design and develop programs for an agent to learn and act in a structured environment.

Learning Resources:	
1	S. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, 3rd Edition, Prentice Hall, 2009.
2	E. Rich, K. Knight and K. Knight, Artificial Intelligence, McGraw Hill, 1991.
3	M.C. Trivedi, A Classical Approach to Artificial Intelligence, Khanna Publishing House, New Delhi, 2018.
4	D. Poole and A. Mackworth, Artificial Intelligence: Foundations for Computational Agents, Cambridge University Press, 2010.