Indira Gandhi Delhi Technical University For Women
(Established by Govt. of Delhi vide Act 09 of 2012)

Course Structure for B. Tech Programme, MAE

Seventh Semester (Fourth Year)

S.No.	Subject Code	Subject Name	L-T-P	Credits	Category
1.	BMA- 401	Finite Element Analysis	3-0-2	4	**DCC**
2.	BMA- 403	Mechatronics	3-0-2	4	**DCC**
3.	BMA- 451	Minor Project	0-0-8	4	**DCC**
4.	BMA- 453	Industrial Training / Internship	-	1	**DCC**
5.	BMA- 4XX	**Department Elective IV**	3-0-2 /3-1-0	4	**DEC**
6.	BMA- 4YY	**Department Elective V**	3-0-2/ 3-1-0	4	**DEC**
		Total		21	

Eighth Semester (Fourth Year)

S. No.	Subject Code	Subject Name	L-T-P	Credits	Category
1	BMA -402	Computer Aided Manufacturing	3-0-2	4	**DCC**
2	BMA -404	**Robotics**	3-0-2	4	**DCC**
3	BMA- 452	Major Project	0-0-16	8	**DCC**
4	BMA- 4ZZ	**Department Elective VI**	3-0-2 /3-1-0	4	**DEC**
5.	GEC-402	Generic Open Elective III	0-2-0 0-0-4 2-0-0	2	**GEC**
		Total		22	

Note: All Industrial training / Internships will be done in summer break of previous academic session. Assessment for the same will be done within first two weeks of opening of academic session by department.

List of Department Elective Courses

Department Elective Course – IV	BMA-405	Tool Engineering	3-0-2
	BMA-407	Welding Technology	3-0-2
	BMA-409	Mechanical Modeling and Simulation	3-0-2
	BMA-411	Flexible Manufacturing System	3-0-2
	BMA-413	Refrigeration and Air-Conditioning	3-0-2
	BMA-415	**E-Learning Based Course-1	
	BMA-429	**Internet of Things**	3-0-2
Department Elective Course – V	BMA-417	Agile Manufacturing	3-0-2
	BMA-419	Hydraulic & pneumatic Control	3-0-2
	BMA-421	Ergonomic Design	3-0-2
	BMA-423	Computational Fluid Dynamics and Heat Transfer	3-0-2
	BMA-425	Hydraulic Machines and Hydro-Power Plant	3-0-2
	BMA-427	**E-Learning Based Course-2	
	BMA-431	Sustainable and Green Manufacturing	3-0-2
	BMA-433	Machine Learning for Mechanical Engineers	3-0-2
Department Elective Course – VI	BMA-406	Advanced Machine Design	3-0-2
	BMA-408	Maintenance and Reliability	3-0-2
	BMA-410	Reverse Engineering and Rapid Prototyping	3-0-2
	BMA-412	Non-Conventional Manufacturing Processes	3-0-2
	BMA-414	Product Design & Development	3-0-2
	BMA-416	**E-Learning Based Course-3	
	BMA-418	Fracture Mechanics	3-0-2
	BMA-420	Non-conventional Energy resources	3-0-2
	BMA-422	Cogeneration and Improved Power cycles	3-0-2
	BMA-424	MEMS & NEMS	3-0-2
	BMA- 426	Design of Experiments	3-0-2
	BMA-428	**Sensors and Actuators**	3-0-2

	BMA-430	Jet Propulsion Systems	3-0-2

Finite Element Analysis	
Course Code: BMA-401	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DCC	

Introduction: The Finite Element Method (FEM) is widely used in industry for analysing and modelling structures and continua, whose physical behaviour is described by ordinary and partial differential equations. The FEM is particularly useful for engineering problems that are too complicated to be solved by classical analytical methods.

Course Objectives: The objectives of this course are

- To introduce advanced element used in Finite Element analysis.
- To introduce nonlinear analysis of structure.
- To introduce formulation of dynamic problems in FEM
- To build the ability to model and to solve complex problems in engineering

Pre-Requisites: Engineering Mechanics, Strength of Materials, Machine Design

Course Outcomes: Having successfully completed this course, the student will

CO1: Understanding of the theoretical basis of the weighted residual Finite Element Method.
CO2: Knowledge about the basic equations used in elasticity
CO3: Knowledge about the soprametric formation and co-ordinate transformation.
CO4: Understanding of stiffness matrix formulation for beam and frame element

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Matrix algebra, the basic concept of FEM, spring and Bar elements, Element stiffness and Assembly stiffness equations by direct and inspection approach, Treatment of boundary conditions, Variational method of approximation (Rayleigh Ritz method, method of weighted residuals), potential energy formulation.	
UNIT II	11 Hours
Basic equation in elasticity, Stresses and strains, Compatibility equations, Strain-displacement relations, One dimensional problems, Linear, Quadratic and cubic elements, Shape functions, compatibility and convergence requirements, Co-ordinate system, Numerical Integration, Gauss Legendre quadrature, Application problems.	
UNIT III	10 Hours
Finite element analysis for plane stress and plane strain problem, Strain displacement matrix for 2-D elements, soparametric formulation, Co-ordinate transformation, global, local and natural co-ordinates, Two dimensional integrals, higher order elements, Application problems. Scalar field problems including heat conduction and flow problems.	
UNIT IV	10 Hours
Stiffness matrix formulation for beam and frame element.	

Introduction of Dynamic analysis, Basic equations, Lagrange's equation, lumped and consistent mass matrices, Eigen-value problems and Eigen-modes, case studies using FEA software – ANSYS, NASTRAN, HYPERMESH etc.

Text Books	
1	T.R. Chandrupatla and Belegundu, "Finite Element in Engineering", Prentice-Hall, 4th edition, 2011.
2	J.N Reddy, "An Introduction to Finite Element", 4th Edition, Mc-Graw Hill, 2020.
3	David Hutton, "Fundamentals of Finite Element Analysis", 1st Edition, McGraw-Hill Science, 2017.
Reference Books	
1	Cook, Malkus, Plesha and Witt, "Concepts and Applications of Finite Element Analysis", 4th Edition, Wiley India, 2007.
2	Liu and Quek, "The Finite Element Method: A Practical Course", 2nd Edition, Oxford, UK, 2013.
3	S.S. Rao, "The Finite Element Method in Engineering", 5th Edition, Butterworth-Heinemann, 2010.
4	C.S. Krishnamurthy, "Finite Element Analysis: Theory and Programming", 2nd Edition, Mc-Graw Hill, 2013.
5	www.nptel.ac.in
6	http://ocw.mit.edu

Mechatronics	
Course Code: BMA-403	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DCC	

Introduction: Mechatronic systems are integrated mechanical, electrical, and computer systems, and are enabling for several important technologies including electric vehicles, disk drives, power and flight control systems, production machinery, and robotics.

Course Objectives: The objectives of this course are to

- Learn about mechatronic systems
- Understand the major conceptual pieces comprising a mechatronic system
- Provide a hands-on experience with electro-mechanical hardware. Develop intuition of how these systems function.
- View systems from a "control" point of view: objectives, actuators, sensors, power, and computer control.
- Become familiar with core electrical and mechanical components

Pre-Requisites: Basic Electronics

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Understand the basics of pneumatic, hydraulic and electric actuation systems.

CO2: Apply the digital electronics and sensors in mechatronic systems.

CO3: Ability to identify the interfacing, data acquisition and signal conditioning requirements for mechatronic systems

CO4: Design of mechatronics systems using PLCs and integrate the mechatronic components to meet product requirements.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Pneumatic & Hydraulic Actuation Systems: Fluid power systems, hydraulic systems, Pneumatic systems, hydraulic pumps and Pressure Control Valves and regulation, Cylinders, Direction Control Valves, Rotary Actuators, Accumulators, Amplifiers, and Pneumatic Sequencing Problems. **Electrical Actuation Systems:** Switching Devices, Mechanical Switches – SPST, SPDT, DPDT, keypads; Relays, Diodes, Thyristors, Transistors, Solenoid Operated Hydraulic and Pneumatic Valves, Electro-Pneumatic Sequencing Problems. Control of DC & AC Motors, Stepper Motors and Servo Motors.	
UNIT II	11 Hours
Digital Electronics and Systems: Gates and Integrated Circuits Like 7408, 7402, Karnaugh Maps, Application of Logic Gates as: Parity Generators, Digital Comparators, BCD to Decimal Decoders, Flip Flops and applications, sequential logic, Introduction to Microprocessor and microcontrollers. **Sensors, Transducers and Application:** Performance Terminology, Static and Dynamic Characteristics, Displacement, Position and Proximity Sensors, Potentiometer Sensors, Strain Gauge Element, LVDT, Optical Encoders, Pneumatic Sensors, Hall Effect Sensors, Tachogenerators, Strain Gauge Load Cell, Thermostats, Photo Darlington. Interfacing Sensors in Mechatronic System.	
UNIT III	10 Hours
System Interfacing and Data Acquisition: Interfacing requirements, Buffers, Darlington Pair, Handshaking, Serial and Parallel Port Interfacing, Peripheral Interface Adapters, Analog to Digital Conversion, Digital to Analog Conversion, Sample and Hold Amplifiers, Multiplexers, Time Division Multiplexing, Digital Signal Processing, Pulse Modulation. **Introduction to Signal Conditioning:** Signal Conditioning Processes, Inverting Amplifiers, Non-Inverting Amplifiers, Summing, Integrating, Differential, Logarithmic Amplifiers, Comparators, Amplifiers Error, Filtering, Wheatstone Bridge, Temperature Compensation, Thermocouple Compensation.	
UNIT IV	10 Hours

Programmable Logic Controllers:
Programmable logic controllers (PLC) Structure, Input / Output Processing, principles of operation, PLC versus computer, Programming Languages, programming using Ladder Diagrams, Logic Functions, Latching, Sequencing, Timers, Internal Relays And Counters, Shift Registers, Master and Jump Controls, Jumps, Data Movement, Code Conversion, Data handling and manipulation, selecting a PLC, ladder programming and cases - Auto-Focus Camera, Printer, Domestic Washing Machine, Optical Mark Reader, Bar Code Reader and Pick and Place robot Arm.

Text Books	
1	W. Bolton, "Mechatronics – Electronic Control Systems in Mechanical & Electrical Engineering", 7th Edition, Pearson Education Ltd., 2018.
2	Nitaigour Premchand Mahalik, "Mechatronics Principles, Concepts & Application", 1st Edition, Tata McGraw Hill Publishing Co. Ltd., 2003.
3	K. P. Ramachandran, G.K. Vijayaraghavan, M.S. Balasundaram, "Mechatronics - Integrated Mechanical Electronic Systems", 1st Edition, Wiley, 2008.
Reference Books	
1	David g Alciatore, Michael B Histand, "Introduction to Mechatronics", 5th Edition, McGraw Hill Education, 2018.
2	A Smaili, F Mrad, "Mechatronics – Integrated Technologies for Intelligent Machines", 1st Edition, Oxford Higher Education, 2008.
3	Clarence W. de Silva, "Mechatronics: A Foundation Course", 1st Edition, CRC Press,2010.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Tool Engineering	
Course Code: BMA-405	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: Tools are the basic components for any machining process. The quality and efficiency of any machining operation basically depends upon quality of tools which in turn depends upon the proper shape, size and material of the tools. Productivity and quality of machining operations may further be enhanced by proper and quick mounting of tools and jobs on machines. Jigs and fixture play an import role in this process. This course attempts to enable students to select a tool of proper size and shape for a required machining operation.

Course Objectives: The objectives of this course are

- To make students understand the importance of tool engineering
- To demonstrate design process of cutting tool
- To present theory and design aspects of jigs and fixtures

Pre-Requisites: Basic knowledge of machine tools.

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Knowledge about the different cutting tool geometry and economics of machining.

CO2: Understanding about the designing of the different cutting tools.

CO3: Understanding of the different principles of locating and clamping and knowledge about designing and drawing the Jigs and fixtures.

CO4: Identify the different types of Sheet Metal Dies.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction to Tool Engineering: Tool Engineering, Tool Classifications, Tool Design Objectives, Tool Design in manufacturing, Challenges and requirements, Tool nomenclature, Fits and Tolerances. **Tooling Materials**: Ferrous and Non-ferrous, Carbides, Ceramics and Diamond -Non-metallic tool materials.	
UNIT II	11 Hours
Design of cutting Tools: Mechanics of Metal cutting, Oblique and orthogonal cutting, Chip formation and shear angle, Single-point cutting tools, milling cutters, Drilling tools, Broaching Tools.	
UNIT III	10 Hours
Design of Jigs and Fixtures: Introduction, Fixed Gages, Gage Tolerances, selection of material for Gages, Principles of location, Locating methods anddevices, Principles of clamping, Drill jigs, General considerations in the design of drill jigs, Drill bushings, **Methods of construction:** Thrust and Turning Moments in drilling, Drill jigs and modern manufacturing, Types of Fixtures, Milling Fixtures, Boring jig, Lathe Fixtures, Grinding Fixtures, Modular Fixtures.	
UNIT IV	10 Hours
Design of Press Tools Types of Sheet Metal Dies, Method of Die operation, Clearance and cutting force calculations, Blanking and Piercing die design, Pilots, Strippers and pressure pads, Presswork materials, Strip layout, Short-run tooling for Piercing, Bending dies, Forming dies, Drawing dies.	

Text Books	
1	Cyrll Donaldson, George H.LeCain, V.C. Goold, "Tool Design", 5th Edition, Tata McGraw

	Hill Publishing Company Ltd., 2017.
2	E.G.Hoffman, “Jig and Fixture Design”, 5th Edition, Thomson Asia Pvt Ltd, Singapore, 2008
3	Venkataraman K., “Design of Jigs, Fixtures and Press tools”, 1st Edition, TMH, 2016.
4	Ostergaard, “Basic Die Making”, MGH, New York, 2013.
5	J.R.Paquin, “Die Design Fundamental", Industrial Press, Inc. New York, NY, USA, 2005
Reference Books	
1	B.J.Runganath, “Metal Cutting and Tool Design”, 2nd Edition, Vikas Publication, 2018.
2	P.C. Sharma, “Machine tools & Tool Design”. 1st Edition, Khanna publishers, 2005.
3	Milton Shaw, “Metal cutting principle”, 1st Edition, CBS Publication, 2012.
4	Eary Reed, “Technique of Press Working Sheet Metal”, Prentice Hall, 1974.
5	Ivana Suchy, “Handbook of Die Design”, New Jersey, Second Edition, Mcgraw-Hill.
6	www.nptel.ac.in
7	http://ocw.mit.edu

Welding Technology	
Course Code: BMA-407	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: This is a basic course welding technology. Students will be introduced to welding processes as well as learn how to perform simulation in welding. Students will learn about welding procedure specifications and various weld testing methods.

Course Objectives: The objectives of this course are

- Identifying various welding technologies& their application in real life
- Enhanced knowledge about welding manipulators and automations equipment
- Ability to develop a WPS for application

Pre-Requisites: Basic knowledge of welding processes

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Model and design welding processes
CO2: Convert conventional welding processes to automated systems
CO3: Analyze and inspect weld joints
CO4: Identify manual, automatic and mechanized welding

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction: Evolution of welding; classification of welding processes; heat sources and shielding methods. Physics of Welding Arc Welding arc, Welding Power Sources. **Arc Welding Processes** Consumable electrode welding processes. Manual metal arc (MMA)welding; Gas metal arc welding; pulsed MIG welding; Submerged arc welding, Significance of flux-metal combination; Electroslag welding: heat generation; principle; Gas tungsten arcwelding; selection of polarity, Plasma arc welding; transferred and non-transferred plasma arcwelding; selection of gases; welding parameters; keyhole technique.	
UNIT II	11 Hours
Heat Flow in Welding: Effect of welding parameter on heat distribution; calculation of peak temperatures; thermal cycles; cooling rate and solidification; Residual stresses and their distribution in welds; influence of residual stresses in static and dynamic loading, distortion **Weldability of Metals:** Solidification of weld metal; heat affected zone (HAZ), factors affecting properties of HAZ; gas-metal, slag-metal and solid-state reactions in welding and their influence on soundness of weld joint; lamellar tearing and hydrogen damage; weldability; definition, factor affecting the weldability of steel Carbon equivalent. weldability of steel, cast iron and aluminium alloys of commercial importance, failure analysis of welded joints.	
UNIT III	10 Hours
Testing and Inspection of Weld Joints Chemical tests; Metallographic tests; Hardness tests; Mechanical test for groove and fillet welds-full section, reduced section and all-weld- metal tensile tests, root, face and side bend tests, fillet weld break tests, creep & fatigue testing. **Non-Destructive Testing of Weldments:** Visual inspection; Dye-penetrant inspection; Magnetic particle inspection; Ultrasonic inspection, principle of ultrasonic testing, Radiographic inspection – principle of radiography, X-ray tubes, gamma-ray sources, Eddy current inspection.	
UNIT IV	10 Hours
Introduction to Welding automation Introduction to welding automation, difference in manual, automatic and mechanized welding. **Welding processes for automation**	

Introduction to welding processes suitable to welding automation, requirements of power source for automation, recent developments in power sources, welding fixtures, positioners and manipulators, orbital welding systems **Simulation in welding** Welding simulation, weld designing, prediction of thermal and metallurgical changes and properties, computerized weld testing, data acquisition and sensing, real time information and control systems, welding documentation, data base and knowledge base systems.

Textbooks	
1	O.P Khanna, "Textbook of welding technology", 1st Edition, Dhanpat Rai Publications, 2015.
2	Ramesh Singh, "Applied Welding Engineering", 2nd Edition, Butterworth-Heinemann, 2015.
3	J. Weston, "Exploiting Robots in Arc Welded Fabrication", 1stEdition , British Welding Research Association, 2007.
4	Leonard. P. Connor, "AWS Welding Handbook Volume-III", 8th Edition, AWS, 1998.
Reference Books	
1	Leonard. P. Connor, "AWS Welding Handbook Volume-I", 8th Edition, AWS, 1998.
2	Parmar R.S, "Welding Engineering and Technology", 1 st Edition, Khanna Publishers, 2013.
3	www.nptel.ac.in
4	http://ocw.mit.edu

Mechanical Modeling and Simulation	
Course Code: BMA-409	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: Modeling and simulation (M&S) is the use of models (e.g., physical, mathematical, or logical representation of a system, entity, phenomenon, or process) as a basis for simulations to develop data utilized for managerial or technical decision making. The use of M&S within engineering is well recognized. Simulation technology belongs to the tool set of engineers of all application domains and has been included inthe body of knowledge of engineering management. M&S helps to reduce costs, increase the quality of products and systems, and document and archive lessons learned.

Course Objectives: The objectives of this course are togive an overview of -

- Various concepts of modelling
- Different computational techniques for simulation.
- Simulation of various mechanical systems
- Simulation of various manufacturing systems

Pre-Requisites: Statistics and probability, Calculus

Course Outcomes: Upon completing the course, the student should have

CO1: Knowledge about the basics of probability and statistics
CO2: Applications of the various systems
CO3: Analysis of the different techniques of simulation
CO4: Evaluation of the various systems such as the continuous and the discrete systems and the linear and the non- linear systems.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction: A review of basic probability and statistics, random variables and their properties, Estimation of means variances and correlation.	
UNIT II	11 Hours
System Modeling: Concept of System and environment, Continuous and discrete systems, Linear and non-linear systems, Stochastic activities, Static and Dynamic models, Principles of modeling, Basic Simulation modeling, system modeling, Role of simulation in model evaluation and studies, advantages of simulation.	
UNIT III	10 Hours
Probability Concepts in Simulation: Stochastic variables, discrete and continuous probability functions, Random numbers, Generation of Random numbers, Variance reduction techniques, Determination of length of simulation runs. **System Simulation:** Techniques of simulation, Monte Carlo method, Experimental nature of simulation, Numerical computation techniques, Continuous system models, Analog and Hybrid simulation, Feedback systems, Computers in simulation studies, Simulation software packages.	
UNIT IV	10 Hours
Simulation of Mechanical Systems: Building of Simulation models, Simulation of translational and rotational mechanical systems, Simulation of hydraulic systems. **Simulation of Manufacturing Systems:** Simulation of waiting line systems, Job shop with material handling and Flexible manufacturing systems, Simulation software for manufacturing and Case studies.	

Text Books	
1	Geoffrey Gordon, "System Simulation", 2nd Edition, PHI Publication, 1979.

2	Aaverill M Law, "Simulation Modeling & Analysis", 4th Edition Mc-Graw Hill, 2017.
3	W. Bolton, "Mechatronics", 1st Edition, Pearson Education (Singapore) Ltd., 2005.
Reference Books	
1	Robert E. Shannon, "System Simulation: The Art and Science", 1st Edition, Prentice Hall, 1975.
2	J. Schwarzenbach and K.F. Gill, "System Modeling and Control", 3rd Edition,Butterworth-Heinemann, 1992.
3	John A. Sokolowski and Catherine M. Banks, "Principles of Modeling and Simulation: A Multidisciplinary Approach", 1st Edition, Wiley Publication, 2009.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Flexible Manufacturing System	
Course Code: BMA-411	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: Flexible manufacturing system (FMS) is an arrangement of machines interconnected by a transport system. The transporter carries work to the machines on pallets or other interface units so that work-machine registration is accurate, rapid, and automatic. A central computer controls both machines and transport system. FMS is the latest subject of interest and research in field of mechanical and automation engineering

Course Objectives: The objectives of this course are

- To Understand the role of Flexible Manufacturing Systems (FMS) in manufacturing,
- To Understand the concept of Group Technology
- To Understand the benefits of automation,
- To provide a basic knowledge of automation equipment,

Pre-Requisites: Basic knowledge of Manufacturing systems

Course Outcomes: After successful completion of the course, the students will-

CO1: Explain the concept of Flexible Manufacturing System.
CO2: Illustrate group technology and its advantages.
CO3: Describe Automate material storage and retrieval system..
CO4: Analyse productivity in different layout of FMS

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction to FMS - concepts, advantages, components of FMS and their integration in the data processing systems - examples of FMS installations. Distributed data processing in FMS –DBMS and their applications in CAD/CAM. **FMS Introduction and Description:** Basic Components of FMS, Different Types of FMS, Types of FMS Layouts, Seeking Benefits on Flexibility, Advantages and Disadvantages of FMS Implementation, Area of Application of a FMS in Industry, Various Equipment and their Functions Required for an FMS, CIM Technology, Manufacturing Cell.	
UNIT II	11 Hours
Group Technology: Introduction, Definition, Visual Inspection, Part Classification and Coding, Production Flow Analysis, Benefits of Group Technology Affecting Many Areas of a Company, Machining Centers, Deburring and Wash Stations, Coordinate Measuring Machines, Types of CMM, Functions of CMM Computer, Operational Cycle Description, CMM Applications, CMM Advantages.	
UNIT III	10 Hours
Automated Material Movement and Storage System: Types of AGVS, Unit Load Carries: Low Built Vehicle, Types A and C, Side Loading and High Lifting Types, Tugger Systems, Automated Guided Transport Carts, Analysis of AGV Systems, Automated Storage and Retrieval Systems (AS/RS), Unit Load AS/RS, Mini Load AS/RS, Carousel AS/RS, Advanced Automated Storage and Retrieval System, Analysis of AS/RS, Quantitative Analysis, Industrial Robots.	
UNIT IV	10 Hours
FMS Software Structure, Functions and Description: General Structure and Requirements, Activities and Functions, Requirements of FMS Software, Work—Order Processing, Data Distribution and Collection, System Diagnostics and Maintenance, Traffic Management and Control, Planning Scheduling and Simulation, Cutting Tools and Tool Management, Tool Delivery, Tool Allocation and Data Flow, Programmable Logic Controllers, FMS Installation and Implementation, Case Studies. Problem Solution by Arena Simulations.	

Textbooks	
1	Mikell P. Groover, “Automation, Production Systems, and Computer-Integrated Manufacturing”, 5^{th} Edition, Pearson Education, 2020.
2	Nand K. Jha, “Handbook of Flexible Manufacturing Systems”, Academic Press, 2012.
3	S.K. Sinha, “CNC Programming”, 1^{st} Edition, Galgotia Publications, 2010.
Reference Books	
1	Heinrich Kuhn, “Flexible Manufacturing Systems”, 1^{st} Edition, John Wiley & Sons Horst Tempelmeier, 1993.
2	S. Joshi, Jeffrey Smith, “Computer control of flexible manufacturing systems: Research and development”, 1^{st} Edition, Springer Science & Business Media, 2012.
3	www.nptel.ac.in
4	http://ocw.mit.edu

Refrigeration and Air-Conditioning	
Course Code: BMA-413	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: This course covers the basics of the theory used behind the working of basic environment control devices like Air-Conditioners and Refrigerators. This course finds application in wide variety of areas ranging from homes to aircrafts covering space shuttles, food storage and transportation, medicine, hospitals, manufacturing and many more.

Course Objectives: The objectives of this course are

- To provide a theoretical basis for indoor environment control.
- To make students aware of different systems used for environment control.
- To enable students to design equipment needed to control the environment of a given space

Pre-Requisites: Thermodynamics and Heat Transfer

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Knowledge about the Air- Refrigeration cycles and systems.
CO2: Evaluation of the different refrigeration systems.
CO3: Knowledge about the different types of refrigerants.
CO4: Knowledge about the factors governing optimum effective temperature.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction to Refrigeration: Definition, Refrigerator, Heat Pump, COP, Unit of Refrigeration. Reversed Carnot Cycle, Classification of refrigeration systems, Numerical problems. **Air-Refrigeration cycles and Systems:** Bell Coleman Cycle, Necessity of cooling the aeroplane, Refrigeration systems for aeroplane – Simple cooling and simple evaporative type, Numerical problems.	
UNIT II	11 Hours
Simple Vapour Compression Refrigeration System: Simple Saturated Cycle, its working, representation on p-h, T-s and p-v diagrams and analysis, Wet and Dry Compression, Effect of foreign materials on the performance of the cycle, Methods of undercooling and Effect, sources of superheating and effects, Pressure losses and their effects on the performance of the cycle, Advantages and disadvantages of Vapour Compression Refrigeration System over air refrigeration system, Numerical problems. **Vapour Absorption Refrigeration System**: Simple vapour absorption Refrigeration system, Practical vapour absorption system, COP of an ideal vapour absorption system, Advantages and disadvantages over vapour compression refrigeration system, Properties of ideal refrigerant, absorbent and refrigerant-absorbent combinations used in absorption system.	
UNIT III	10 Hours
Refrigerants: Classification of refrigerants, Required properties of an ideal refrigerant, Designation of refrigerants, commonly used refrigerants. **Psychrometry**: Definitions of Psychrometric terms and properties, Dalton's Law of Partial Pressures, Psychrometric relations, Psychrometric chart, Psychrometric processes and their representation on Psychrometric chart for calculations, Numerical problems.	
UNIT IV	10 Hours
Comfort Air Conditioning: Requirements of comfort air conditioning, Concept of Effective Temperature, Comfort chart and comfort zone, Factors governing optimum effective temperature. **Air conditioning systems:** Summer air conditioning system, winter air conditioning system, year-round air conditioning system. **Load Estimation**: Heating/cooling load components, infiltration, air changes, load calculation.	

Textbooks	
1	P.L. Ballaney, “Refrigeration and Air Conditioning”, Khanna publishers, 2009.
2	C P Arora, “Refrigeration and Air Conditioning”, Mc-Graw Hill, 3rd Edition 2017.
3	Arora and Domkundwar, “A Course in Refrigeration and Air Conditioning”, Dhanpat Rai Publications, 7th edition, 2018.
4	Manohar Prasad, “Refrigeration and Air conditioning”, New Age Publication, 2nd edition, 2015.
Reference Books	
1	J. Roy Dossat, “Principles of Refrigeration”, Pearson Education Asia Publication, 4th edition 2002.
2	Ananthanarayan, “Basic Refrigeration & Air Conditioning”, 4th Edition, Mc-Graw Hill, 2013.
3	Pita Edward G, “Air Conditioning Principles and Systems”, Prentice Hall, 4th edition, 2001.
5	www.nptel.ac.in
6	http://ocw.mit.edu

Internet of Things	
Course Code: BMA-429	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: Internet of Things known as IoT is the study that describes the network of objects that are different things which are embedded with sensors, software, and other technologies to connect and exchange data with other systems and devices over the Internet. IOT has wide applications in the areas ranging from healthcare, manufacturing, business, defence etc. It has become an important aspect of automation and the area is growing very rapidly as innovative IOT solutions are required in both academia and industry as the reliance on IOT is increasing rapidly.

Course Objectives: The objectives of this course are

- Understand core technology, applications, sensors used and IOT architecture along with the industry perspective.
- Principles and operations of different types of sensors commonly used on mobile platform will be taught in a manner that by the end of the course the students will be able to design and implement realtime solutions using IOT.

Pre-Requisites: Basic knowledge of machine learning and sensor devices.

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Understand concept of IOT and ability to implement in real time scenarios

CO2: Design solutions based on IOT architecture and applications in various fields

CO3: Analyze security and privacy issues in IOT

CO4: Apply knowledge to Design and develop various applications of sensors in Industrial, healthcare,commercial, and building automation.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction to IoT: What is IoT, how does it work? Difference between Embedded device and IoT device, Properties of IoT device, IoT Ecosystem, IoT Decision Framework, IoT Solution Architecture Models, Major IoT Boards in Market. **Setting Up Raspberry/Arduino to Create Solutions:** Explore Raspberry Pi, setting up Raspberry Pi, showing working of Raspberry Pi using SSH Client and Team Viewer, Understand Sensing actions, Understand Actuators and MEMS	
UNIT II	11 Hours
Communication Protocols used in IoT: Types of wireless communication, Major wireless short range communication devices, properties, comparison of these devices Bluetooth, WIFI, ZigBee, 6LoWPAN), Major wireless Long-range communication devices, properties, comparison of these devices (Cellular IoT, LPWAN)	
UNIT III	10 Hours
IoT Applications: Industrial Internet 4.0, Applications such as: Smart home, wearables, smart grid, connected car, connected health (digital health, telehealth, telemedicine), smart retail, digital clone.	
UNIT IV	10 Hours
Sensors: Applications of various sensors: Google Maps, Waze, Whats App, Ola Positioning sensors: encoders and accelerometers, Image sensors: cameras, Global positioning sensors: GPS, GLONASS, IRNSS, Galileo and indoor localization systems, Motion & Orientation Sensors: Accelerometer, Magnetometer, Proximity Sensor, Gyroscope Calibration, noise modelling and characterization and-noise filtering and sensor data processing. Privacy &Security.	

Textbooks	
1	Vijay Madisetti and ArshdeepBahga, "Internet of Things (A Hands-on Approach)", 1st Edition, VPT 2014.
2	Francis daCosta, "Rethinking the Internet of Things: A Scalable Approach to Connecting Everything", 1st Edition, Apress Publications. 2013.
3	Cuno Pfister, "Getting Started with the Internet of Things", 1st Edition, O'Reilly Media, 2011
Reference Books	
1	Kyung, C.-M., Yasuura, H., Liu, Y., Lin, Y.-L., "Smart Sensors and Systems", 1st Edition, Springer International Publishing, 2015.
2	Jan Holler, VlasiosTsiatsis, Catherine Mulligan, Stefan Avesand, Stamatis Karnouskos, David Boyle, "From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence", 1st Edition, Academic Press, 2014.
3	Peter Waher, "Learning Internet of Things", 1st Edition, Packt Publishing, 2015.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Agile Manufacturing	
Course Code: BMA-417	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: Agile Manufacturing is an approach to manufacturing that leverages flexibility, bottom-up innovation, and augmentation in order to adapt, through an iterative process, to changing conditions.

Course Objectives: The objectives of this course are

- To impart knowledge on the pace of changes in the manufacturing technology.
- To familiarize students with the principles of agile manufacturing processes.
- To impart the knowledge of implementing various tools and techniques of agile manufacturing environment.

Pre-Requisites: Production Engineering

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Describe the principles of agile manufacturing
CO2: Recognize the potential applications of agile manufacturing
CO3: Apply the tools/techniques of agile manufacturing to industrial problems
CO4: Explain the methods of measurement of agility.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Types of Production- The Agile Production Paradigm- History of Agile Manufacturing- Agile Manufacturing Vs Mass Manufacturing, Agile Manufacturing Vs Mass Customization- Agile Manufacturing Research Centers.	
UNIT II	11 Hours
Agile Practices- Agile practice for product development - Manufacturing agile practices - understanding the value of investing in people, Concept models of Agile Manufacturing- Infusing managerial principles for enabling agility.	
UNIT III	10 Hours
Implementing technology to enhance agility- Implementing new technology – reasons – guidelines preparation for technology implementation - A checklist, technology applications that enhance agility - agile technology make-or-buy decisions.	
UNIT IV	10 Hours
Performance Measurement and Costing: Measurement of agility – methods – Scoring and Fuzzy approaches – Costing for Agile Manufacturing practices – Activity Based Costing. Creating the learning factory: Imperative for success, factory becoming a learning factory, building a road map for becoming a learning factory - core capabilities, guiding vision, leadership that fits, ownership and commitment, pushing the envelope, prototypes, integration, learning challenges for learning manufacturing business.	

Text Books	
1	Gunasekaran A, "Agile Manufacturing, 21st Strategy Competitiveness Strategy", Elsevier Publications, 2001.
2	Gopalakrishnan "Simplified Lean Manufacture – Elements, Rules, Tools and Implementation", PHI Learning Private Limited, New Delhi, India, 2010.
3	Devadasan, S.R., Sivakumar, V., Mohan Murugesh, R., Shalij, P, R. "Lean and Agile Manufacturing: Theoretical, Practical and Research Futurities", Prentice Hall India, 2012.

Reference Books	
1	Goldman S L, Nagal R N and Preiss K, “Agile Competitors and Virtual Organizations”, Van Nostrand Reinhold, 1995.
2	Brian H Maskell, “Software and the Agile Manufacturer, Computer Systems and World Class Manufacturing, Productivity Press, 1993
3	Paul T. Kidd, “Agile Manufacturing -Forging new Frontiers”, Addison Wesley Publication-1994.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Hydraulic & Pneumatic Control	
Course Code: BMA-419	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction:
The concepts of hydraulics and pneumatics are important and indispensable tools being used in the innovations, circuit design and improvement of engineering processes and devices. Different types of power sources, valves and actuators are essential elements in all the manufacturing industries, specially where automation and control is required. This course is designed to develop underpinning knowledge of hydraulic and pneumatic systems which are widely used for control and other purposes in machine tools, material handling, automobile, marine, elevators, mining, metal processing equipment and other fields. This course also enables the diploma students to operate and troubleshoot different types of hydraulic and pneumatic systems in industries

Course Objectives: The objectives of this course are
- To provide student with knowledge on the application of fluid power in process, construction, and manufacturing Industries.
- To provide students with an understanding of the fluids and components utilized in modern industrial fluid power system.
- To develop a measurable degree of competence in the design, construction, and operation of fluid power circuits.

Pre-Requisites: NIL

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Understand the basics of Fluid power and operation of different types of pumps and motors.
CO2: Analyze the different valves used in hydraulic systems.
CO3: Identify the working of different pneumatic circuits and systems and calculations of acting cylinders.
CO4: Apply the concepts in the implementation of hydraulic and pneumatic systems.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Advantages and Disadvantages of Fluid control, Types of Hydraulic Fluids, physical, chemical and thermal properties of hydraulic fluids, selection of hydraulic fluid, fluid flow fundamentals **Hydraulic Pumps and Motors:** Basic Types and constructions, ideal pump and motor analysis, Performance curves and parameters	
UNIT II	11 Hours
Hydraulic Control Valves: Valve configurations, general valve analysis, critical centre, open centre, three-way spool valve analysis and Flapper valve analysis, pressure control valves, single and two stage pressure control valves, flow control valves, introduction to electro hydraulic valves. **Hydraulic Power Elements:** Valve controlled motor, valve controlled piston, three way valve controlled piston, and pump controlled motor, pressure transients in power elements.	
UNIT III	10 Hours
Characteristics of Pneumatics, Applications of Pneumatics, Basic Pneumatic elements, Steady flow of Ideal gases, orifice and nozzle calculations, capillary flow, flow of real gases, linear flow equations in Orifices and Nozzles.	

Steady state analysis of pneumatic components: Multiple restriction and volume calculations, sensing chambers, valves, Single acting actuators.	
UNIT IV	10 Hours
Transients in elementary pneumatic systems: Linear dynamics-linear pneumatic spring rate, Applications in industrial process controls: On-Off pneumatic feedback systems, feedback control of proportional gain, derivative action, integral action.	

Text Books	
1	Herbert E. Merritt, “Hydraulic Control Systems”, 1st Edition, John Wiley & Sons, 2005.
2	B.W. Anderson, “The Analysis and Design of Pneumatic Systems”, 1st Edition, Wiley, 1980.
3	A.B. Goodwin, “Fluid Power Systems”, 1st Edition, Macmillan, 1989.
Reference Books	
1	Anthony Esposito, “Fluid power with applications”, Prentice Hall, 7th Edition, 2008.
2	Arthur Akers, Max Gassman, Richard Smith, “Hydraulic Power System Analysis”, 1st Edition, Taylor and Francis Group, 2006.
3	John Pippenger& Tyler Hicks, “Industrial Hydraulics”, 3rd edition McGraw Hill, 1980.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Ergonomic Design	
Course Code: BMA-421	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: An introduction to ergonomics affording students the necessary knowledge essential for the psychological and anthropometrical development leading to good design. Emphasis is placed on health and safety.

Course Objectives: The objectives of this course are

- To Accurately recognize and evaluate hazards (ergonomic in nature) which are likely to cause occupational illnesses or injuries.
- To Design and redesign tasks and workstations to fit employees.
- To Apply the knowledge, skills, and abilities obtained into an industrial based problem.

Pre-Requisites: Basic knowledge of statistics; means, standard deviations, and percentiles.

Course Outcomes: After successful completion of the course, the students will -

CO1: Knowledge of the sciences of human factors and workplace ergonomics.
CO2: Evaluation of the Musculoskeletal disorders.
CO3: Knowledge about the cognitive aspects of user- system interaction
CO4: Analyze the environmental factors influencing human performance.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Definition, History and Scope of Human Factors/Ergonomics; Principles of fitting design configurations to the users; Man-machine-environment interaction system: A design perspective; Human compatibility, comfort, and adaptability.	
UNIT II	11 Hours
Physical aspects of human factors: anthropometrics, human body structure and function, posture, joint movement, and biomechanics. Occupational stress and Musculoskeletal disorders; Safety and health issues.	
UNIT III	10 Hours
Cognitive aspects of user-system interaction: perception, information processing, user behaviour, error and risk perception; Principles of human factors in visual communication;	
UNIT IV	10 Hours
Visual display in different planes- static shape, size, font type and dynamic characters of display; Environmental factors influencing human performance; Participatory ergonomics aspects	

Text Books	
1	Kroemer, K.H.E., "Fitting the Human: Introduction to Ergonomics", 7th Edition, CRC Press, 2017.
2	Pheasant, S. & Haslegrave, C., "Bodyspace: Anthropometry, Ergonomics, and the Design of Work", 3rd Edition, CRC Press,2005.
3	Andris Freivalds, Benjamin Niebel "Methods, Standards and Work Design", 13th Edition, McGraw Hill, 2013.
Reference Books	
1	Jordan, P.,"An Introduction to Usability", 1st Edition, Taylor & Francis, 1998.
2	Marcelo M. Soares, Francisco Rebelo "Ergonomics in Design Methods and Techniques", 1st Edition, CRC Press, 2016.
3	K. H. E. Kroemer, H. B. Kroemer, Katrin E. Kroemer-Elbert, "Ergonomics: How toDesign for Ease and Efficiency", 2nd Edition, Prentice Hall, 2000.
5	www.nptel.ac.in

Computational Fluid Dynamics and Heat Transfer	
Course Code: BMA-423	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: Computational Fluid Dynamics and Heat Transfer has become a vital course in the domain of Mechanical Engineering. Ranging from equipment like pumps and turbines to aerodynamics, CFD plays a very crucial role. This course gives the introduction to computational methods being used to simulate heat transfer and fluid flow and provides skills to students that are now much needed in industry as well as in academia.

Course Objectives: The objectives of this course are

- To introduce students to the techniques used in computational heat transfer and fluid flow.
- To make student aware of the errors in computational methods and how to overcome those.
- To enable students to carry out fluid flow and heat transfer simulations and interpret their results.
- To familiarize students with the combination of computational power and mathematics dealing with engineering applications.

Pre-Requisites: Mathematics – I, Numerical Methods, Heat Transfer, Fluid Dynamics

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Knowledge about the different types of methods such as the finite difference methods, finite volume methods and finite element methods
CO2 Knowledge about the general methods to construct FDE
CO3: Knowledge about the general methods to construct FDE
CO4: Analyze the flow algorithms

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Review of Fluid Dynamics and Heat Transfer: Review of Continuity, Momentum and Energy Equations. **Partial Differential Equations:** Introduction and classification of Partial Differentiation Equations. Boundary and Initial Conditions. Mathematical behaviour of partial differential equations. **Fundamentals of Discretization:** Introduction to different types of methods Finite Difference Methods, Finite Volume Methods and Finite Element Methods.	
UNIT II	11 Hours
Application of FDM: Steady and unsteady one and two-dimensional heat conduction equations, one-dimensional wave equations, General method to construct FDE (FTFS, FTBS and FTFS). Convergence, consistency, explicit, implicit and C-N methods. **Grid System and Errors analysis:** Structured/Unstructured grids, Grid Generation Methods, Order of error, Consistency and Stability of Finite Difference Methods. **Point Iterative/Block Iterative Methods:** Gauss-SeidelIteration (Concept of Central Coefficient and Residue, SOR), Different Acceleration Techniques, Sources of Uncertainties, Studies on Grid Independence, TDMA and ADI Techniques.	
UNIT III	10 Hours
Finite Volume Methods: Generating Cartesian grids, problem formulation in FVM, Handling of BCs in FVM. **Upwinding:** Upwinding of convective terms and its significance, Transportive and conservative properties. Upwind biased difference schemes and its significance.	
UNIT IV	10 Hours
Solution of 2-D Fluid Problems: Stream Vorticity Approach **Flow Algorithms:** Mac-Cormack and SIMPLE (Semi-Implicit Method for Pressure Linked Equations).	

Textbooks	
1	Anderson Jr. J.D., "Computational Fluid Dynamics", 1st Edition, Tata McGraw Hill, 2017.
2	Pletcher R.H.,Tannehill J.C., Anderson D.A., "Computational Fluid Mechanics and Heat Transfer", 3rd Edition, CRC Press, 2012.
3	Ghoshdastidar P.S., "Computer Simulation of Flow and Heat Transfer", 4th Edition, Tata McGraw-Hill, 1998.
Reference Books	
1	PatankarSuhas V., "Numerical Heat transfer and Fluid Flow," 1st Edition, Hemisphere, New York, 1980.
2	Versteeg H.K. and Malalasekara W., "An Introduction to Computational Fluid Dynamics – The Finite Volume Method," 2nd Edition, Longman, UK, 2008.
3	Chung T.J., "Computational Fluid Dynamics," 2nd Edition, Cambridge University Press, 2010
4	www.nptel.ac.in
5	http://ocw.mit.edu

Hydraulic Machines and Hydro-Power Plant	
Course Code: BMA-425	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: Hydro Power or Hydroelectricity is a renewable source of electricity. This course gives an introduction to the basic machinery that is used to extract power from flowing water along with a basic understanding of the working of a hydro-electric power plant.

Course Objectives: The objectives of this course are

- To introduce students to various types of hydraulic machines.
- To enable students to assess the various hydraulic machines based on their performance characteristics
- To introduce various types of machines used to extract power from flowing water
- To introduce Hydro Electric Power Plants.

Pre-Requisites: Fluid Mechanics

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Knowledge about the basics of turbo machinery
CO2: Knowledge about the centrifugal and reciprocating pumps
CO3: Analysis of the Hydraulic turbines
CO4: Identify the essential elements of hydro-electric power plant.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Basics of turbo machinery: hydrodynamic force of jets on stationary and moving flat, inclined, and curved vanes, jet striking centrally and at tip, velocity diagrams, work done and efficiency, flow over radial vanes.	
UNIT II	11 Hours
Centrifugal pumps: classification, working, work done – manometric head- losses and efficiencies- specific speed- pumps in series and parallel-performance characteristic curves, cavitation & NPSH. Reciprocating pumps: Working, Discharge, slip, indicator diagrams.	
UNIT III	10 Hours
Hydraulic Turbines: classification of turbines, impulse and reaction turbines, Pelton wheel, Francis turbine and Kaplan turbine-working proportions, work done, efficiencies, hydraulic design –draft tube- theory, functions and efficiency. Performance of hydraulic turbines: Geometric similarity, Unit and specific quantities, characteristic curves, governing of turbines, selection of type of turbine, cavitation, surge tank, water hammer.	
UNIT IV	10 Hours
Hydro Electric Power Plant: Introduction, classifications, essential elements, pumped storage systems, micro and mini hydel power plants, advantages and disadvantages of water power, storage and pondage, essential elements of hydro-electricpower plant.	

Text Books	
1	P.N. Modi& S.M. Seth,“Hydraulics and Fluid Mechanics Including Hydraulics Machines”, 22nd Edition, Rajsons Publications, 2019.
2	R.K.Rajput, “Fluid Mechanics and Hydraulic Machines”, 6th Edition, S. Chand Publications, 2016.
3	R.K. Bansal, “A Textbook of Fluid Mechanics and Hydraulic Machines”, 10th Edition, Laxmi Publications (P) Ltd., 2018.
Reference Books	
1	D.S. Kumar, “Fluid Mechanics and Fluid Power Engineering”, 1st Edition, Kotaria& Sons,

	2013.
2	Dandekar and Sharma,“Water Power Engineering”, 2nd Edition, Vikas Publishing house, New Delhi, 2013.
3	P.S. Nigam, “Handbook on Hydro Electric Engineering”, Nem Chand & Bros., 2008.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Sustainable and Green Manufacturing	
Course Code: BMA-431	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 8
Course Category: DEC	

Introduction: This subject will introduce the students to a new and much-needed concept of green manufacturing. Environment performance is very important nowadays by manufacturing industries and this course also fulfil the SDG 12.

Course Objectives: The objectives of this course are

- To Correlate the green manufacturing to corporate success.
- To focus on the environment as the performance parameters
- To understand the importance of carbon footprint

Pre-Requisites: NIL

Course Outcomes: After successful completion of the course, the students will be able to –

CO1: Knowledge about the importance of green and sustainable manufacturing.
CO2: Understanding about environmental performance.
CO3: Knowledge about lean manufacturing.
CO4: Evaluation of carbon footprint and methods of reduction.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail. Industrial case studies to be analyzed.

Contents:

UNIT I	11Hours
Environmental Justice, Sustainability as the Next Environmental Revolution, Sustainable Manufacturing, Environmental Awareness and Social Responsibility, Greening the Supply Chain, Life Cycle Analysis Sustainability related to Manufacturing, Case studies of manufacturing industry	
UNIT II	11 Hours
Green Manufacturing Practices, Environment Sustainability and impact assessment, Green Manufacturing Management, Productivity with green manufacturing, Sustainability framework, Case studies related to productivity and environment performance parameters.	
UNIT III	14 Hours
Lean manufacturing, definition, explaining basic concepts, value stream mapping, TQM and 6sigma, JIT, Kanban, Push and Pull, applications in manufacturing, performance measures, applications in the manufacturing industry.	
UNIT IV	7 Hours
Energy-intensive manufacturing processes, Calculations of Carbon footprint and methods of reduction, Value Stream mapping techniques, Case studies for Sustainability and Green factories and manufacturing units	

Textbooks	
1	Dornfeld, David A, "Green manufacturing: fundamentals and applications". 1st Edition, Springer Science & Business Media, 2012.
2	Parsons, David, and Kathryn MacCallum. "Agile and lean concepts for teaching and learning." Agile and Lean Concepts for Teaching and Learning". 1st Edition, Springer Singapore, 2019.
3	Davim, J. Paulo, "Sustainable manufacturing". 1st Edition, John Wiley & Sons, 2013.
Reference Books	
1	"Green Manufacturing: Case Studies in Lean and Sustainability" by Association for

	Manufacturing Excellence, 2009.
2	Gunasekaran, Angappa. "Agile manufacturing: the 21st century competitive strategy". 1^{st} Edition, Elsevier, 2001.
3	www.nptel.ac.in
4	http://ocw.mit.edu

Machine Learning for Mechanical Engineers	
Course Code: BMA-433	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: Machine learning has found applications in almost all engineering areas both in academics and industry. In mechanical engineering it has wide applications from defect detection to intelligent robotics and optimised simulations. It has become crucial for mechanical engineers to explore this area.

Course Objectives: The objectives of this course are

- To formulate machine learning problems corresponding to different applications.
- To understand a range of machine learning algorithms along with their strengths and weaknesses.
- To develop reasoning behind Model selection, model complexity, etc.
-

Pre-Requisites: Engineering Mathematics, Numerical Methods, Probability and Statistics

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Design and implement machine learning solutions to classification, regression and clustering problems

CO2: Evaluate and interpret the results of the different ML techniques.

CO3: Design and implement various machine learning algorithms in a range of Real-world applications.

CO4: Knowledge about mathematical computing with Python packages.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Python Introduction: Loops and Conditions and other preliminary stuff, Functions, Classes and Modules, Exceptions, Database access, Mathematical computing with Python packages like: numpy, Mat- plot Lib, pandas Tensor Flow, Keras	
UNIT II	11 Hours
BASICS OF MACHINE LEARNING: Applications of Machine Learning, processes involved in Machine Learning, Introduction to Machine Learning Techniques: Supervised Learning, Unsupervised Learning and Reinforcement Learning, Real life examples of Machine Learning.	
UNIT III	10 Hours
SUPERVISED LEARNING: Classification and Regression: K-Nearest Neighbour, Linear Regression, Logistic Regression, Support Vector Machine (SVM), Evaluation Measures: SSE, MME, R2, confusion matrix, precision, recall, F Score, ROC-Curve.	
UNIT IV	10 Hours
UNSUPERVISED LEARNING: Introduction to clustering, Types of Clustering: Hierarchical Agglomerative Clustering and Divisive clustering; Partitioned Clustering - K-means clustering, Principal Component Analysis, ICA.	

Textbooks	
1	Tom Mitchell, "Machine Learning", 1st Edition, McGraw Hill, 2017
2	Christopher M. Bishop, "Pattern Recognition and Machine Learning", 1st Edition, Springer, 2011
3	Yuxi (Hayden) Liu, "Python Machine Learning By Example", 1st Edition, Packet Publishing Limited 2017
Reference Books	
1	T. Hastie, R. Tibshirani, J. Friedman. "The Elements of Statistical Learning", 2nd Edition, 2017

2	R. O. Duda, P. E. Hart, and D.G. Stork, Pattern Classification, John Wiley and Sons, 2012.
3	Simon O. Haykin, Neural Networks and Learning Machines, Pearson Education, 2016
5	www.nptel.ac.in
6	http://ocw.mit.edu

Computer Aided Manufacturing	
Course Code: BMA-402	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DCC	

Introduction: In this course students will learn about basics of CNC programming, various codes. Students will learn about automation in manufacturing with an introduction to CIM, assembly lines and computerized numerical control. This course will broaden their understanding of automation in manufacturing.

Course Objectives: The objectives of this course are

- To impart fundamental knowledge to students in the latest technological topics on Computer Aided Design, Computer Aided Manufacturing and Computer Aided Engineering Analysis and to prepare them for taking up further research in the areas
- To create congenial environment that promotes learning, growth and imparts ability to work with inter-disciplinary groups in professional, industry and research organizations.
- To broaden and deepen their capabilities in analytical and experimental research methods & analysis of data

Pre-Requisites: NIL

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Classify CNC Machine Tools and their operations .

CO2: Illustrate CNC Lathe, CNC Drilling operations and their components .

CO3: Part programming for different components.

CO4: Analyse Complexity and machining allowance in part programing.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction: Brief introduction to CAD and CAM – Manufacturing Planning, Manufacturing control- Introduction to CAD/CAM **Computer Aided Process Planning (CAPP)** – Advantages and limitations of CAPP, applications, Logical Steps in Computer Aided Process Planning. **Programmed Automation and Numerical Control:** Program controlled machine tools, punched card and punched tape machine tools, numerical control and its basics, axis designation, NC motion control systems: point-to-point, straight-cut and continuous path control systems, applications of NC in metal-cutting and non-metal cutting areas.	
UNIT II	11 Hours
Computer Numerical Control: Block diagrams of CNC operations, nomenclature, types and features of CNC machine tools, elements of CNC machines and systems, machine control unit, position control and its significance, engineering analysis of NC positioning systems, open loop and closed loop systems, precision in NC positioning systems: control resolution, accuracy and repeatability.	
UNIT III	10 Hours
Part Programming: Process planning and flow chart for part programming, tooling systems, tool nomenclature and tool geometries of modern indexable carbide tools, tool pre-setting & modular tooling, selection of tools based on machining capacity, accuracy and surface finish, elements ofprogramming for turning and milling, composition of a part program. Preparatory codes G, Miscellaneous functions M. Interpolation, tool compensations, cycles for simplifying programming, partprogramming for typical components on turning machines and machining centres, computer aided programming.	
UNIT IV	10 Hours
Automated Production Lines and Assembly Systems: Fundamentals, system configurations, applications, automated flow lines, analysis of transfer lines, fundamentals of automated assembly	

systems, numerical problems.

Functions and Components of CIM System: Concept of CAD/CAM integration and CIMS; Feasibility study for CIM implementation, Product development cycle in CIM, evolution of CIM, enabling technologies in CIM, programming in CIM.

Text Books	
1	Radhakrishnan. P, "CAD/CAM/CIM", 4th Edition, New Age International Pvt Ltd, 2018.
2	Venkateshwaran N, "Computer Integrated Manufacturing", 1st Edition, PHI Learning, 2010.
3	Ibrahim Zeid, "CAD/CAM Theory and Practice", 1st Edition, McGraw-Hill Publications, 1991.
Reference Books	
1	S.K. Sinha, "CNC Programming", 1st Edition, Galgotia Publications, 2010.
2	P N Rao, N Tewari, T.K. Kundra, "Computer Aided Manufacturing", 1st Edition, Mc-Graw Hill Publications, 2017.
3	Mikell P. Groover, "Automation, Production Systems and Computer-Integrated Manufacturing", 4th Edition, Pearson Education, 2016.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Robotics	
Course Code: BMA-404	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DCC	

Introduction: The study of robotics concerns itself with the desire to synthesize some aspects of human function by the use of mechanisms, sensors, actuators, and computers. This subject provides an important background material to students involved in understanding the basic functionalities of robotics. This course also provides the most fundamental knowledge to the students so that they can understand the basics of Artificial Intelligence.

Course Objectives: The objective of this course is

- To provide an introduction to robotics including robot classifications.
- To provide design and selection, analysis, sensing and control, and applications in industry.
- To develop basic knowledge of Artificial intelligence, its applications, and techniques.

Pre-Requisites: Kinematics and Dynamics of Machines

Course Outcomes: After successful completion of the course, the students will be able to -

XO1: Knowledge of the robotics including robot classification, design and selection, analysis, sensing and control, and applications in industry.

CO2: Analysis of Robot Kinematics, Dynamics, and motion planning.

CO3: Applications of the various types of sensors and controller that are used in robotics.

CO4: Knowledge of Robot Programming to students.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers,projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Fundamentals of Robotics: Robot definition, automation for robotics, classification of robots, Robot anatomy, Work space volume, Drive systems. Control systems. Accuracy and repeatability. Robot design configuration, Components and robotic systems. Robot configurations.	
UNIT II	11 Hours
Robot drive, Sensors, Actuators and Control: Robot drive systems- Hydraulic. Pneumatic & Electric. Robot sensors- Contact and noncontact type sensors, Force and Torque sensor, Robotics vision system, Basic control systems concept and models, controllers, Control system analysis. **End effectors:** Types of grippers. Tools as end effectors. Robot and effectors interface. Gripper selection and design, current and emerging issues in Robotics.	
UNIT III	10 Hours
Robot Kinematics and Dynamics: Mapping, Homogeneous transformations, Rotation matrix, Forward Kinematics Denavit - Hartenberg (DH) representation, inverse kinematics: solution of inverse problems. Lagrangian and Newtonian mechanics, Introduction to Dynamics of Robots. **Robot Differential Motion:** Linear and Angular velocity of rigid link, Velocity and angular velocity and acceleration along link, Manipulator Jacobian, Static force analysis with Jacobian.	
UNIT IV	10 Hours
Trajectory Planning: Basics of Trajectory planning, Joint space trajectory planning, Cartesian Space trajectories, Numericals. **Robot Programming Language & Applications:** Methods of Robot Programming, Lead through Programming Methods, Robot languages and classifications, Role of AI in Robotics and Case studies.	

Text Books	
1	S.K. Saha, “Robotics”, Tata Mc Grow Hills Pvt. Ltd. 2^{nd} Edition, 2014.
2	Mikell P Grover, Mitchell Weiss, “Industrial Robotics: Technology, Programming and

	Application", 2nd Edition, Tata Mc-Graw & Hills, 2017.
3	Saeed B. Niku, "Introduction to Robotics Analysis, Systems & Applications", 3rd Edition, Pearson Education Singapore P. Ltd., 2020.
3	E. Rich and K. Knight, "Artificial intelligence", 3rd Edition, TMH, 2017.
4	Nilsson, N. J. "Principles of artificial intelligence", 1st Edition, Morgan Kaufmann, 2002.
Reference Books	
1	J.J. Craig, "Introduction to Robotics". , 4th edition, Addison Wesley N Delhi, 2018
2	K. S. Fu., "Robotics", 1st Edition, Mc Grow Hill International Editions, 2017.
3	Luger, G. F., Stubblefield, W. A. "Introduction to AI and Expertsystems", 1st Edition, 1989
4	www.nptel.ac.in
5	http://ocw.mit.edu

Advanced Machine Design	
Course Code: BMA-406	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: The course is intended to strengthen the fundamentals of applied mechanics of solids and build an understanding of the design and analysis of machine components under dynamic loading. The course also includes fundamentals and application of fracture mechanics and surface failures in machine component design

Course Objectives: The objectives of this course are

- To study design concepts to enhance the basic design under static /dynamic loading.
- To study behaviour of mechanical components under fatigue and creep.
- To study the surface failures and fatigue failure of the mechanical components.

Pre-Requisites: Machine design

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Identify the factors affecting fatigue behaviour.

CO2: Knowledge about incorporating effect of fatigue, crack and creep for the design and analysis of components.

CO3: Analyze mechanical components subjected to dynamic loading and understand various types of fractures

CO4: Knowledge about basic constitutive relations and rheological models

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and are also e-mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	12Hours
Introduction, Plane Stress, Rotation of Coordinate Axes, Generalized Plane Stress, Principal Stresses and Maximum Shear Stress, 3D state of stress, Stresses on Octahedral plane, Plane strain, Strain gage rosettes. Introduction to basic Constitutive Relations and Rheological Models: Elastic (Generalized Hooke's Law), Plastic (Rigid-Perfectly Plastic, Elastic-Perfectly, Elastic-Linear Hardening), Creep (Steady state and Relaxation, Transient), Anisotropic and Orthotropic Hooke's Law, Theories of Failures: Distortion Energy, Maximum-Shear Stress, Maximum Normal Stress, Modified Coulomb-Mohr Theory, Comparison of theories of failures.	
UNIT II	10 Hours
Fracture Mechanics: Introduction, Rise in stresses due to crack, Crack tip opening displacement, LEFM: Effect of crack on strength of ductile and brittle material, Crack opening modes and Griffith theory, Concept of SIF and Crack Tip Plasticity, Use of K in design and analysis, Determination of plastic zone, size and shape, Limitations of LEFM.	
UNIT III	10 Hours
Introduction, factors affecting fatigue behaviour, Theoretical stress concentration factor and notch sensitivity factor, Fatigue under complex stresses, cumulative fatigue design, Linear damage (Miner's Rule), Manson's 18 25 method, Fatigue crack propagation and life estimation for constant and variable amplitude stress	
UNIT IV	10 Hours
Surface Failures: Friction: Rolling, Effect of roughness, velocity and lubrication on friction, Wear: Adhesive, Abrasive and Corrosive, Lubrication: Hydrodynamic, hydrostatic and elsatorydrodynamic lubrication, Surface Fatigue, Contact Stresses: Spherical, Cylindrical, General and Dynamic, Surface Fatigue Strength, design to avoid surface fatigue Creep and Damping True stress and true strain, Creep phenomenon, Creep Curve, Creep parameters, time-temperature parameters and life estimate: Sherby-Dorn and Larson-Miller, Stress relaxation.	

Textbooks	
1	Norman E. Dowling, Stephen L. Kampe, Milo V. Kral, "Mechanical Behavior of Materials: Engineering Methods for Deformation, Fracture, and Fatigue", 5th Edition, Pearson, 2019.
2	Robert Norton, "Machine Design: An Integrated Approach", 6th Edition, Pearson Education, 2019.
3	Prashant Kumar, "Elements of Fracture Mechanics", 1st Edition, McGraw-Hill, 2009
4	M.N. Shetty, "Dislocations and Mechanical Behaviour of Materials", 1st Edition, PHI, 2013.
Reference Books	
1	R C Juvinall& K M Marshek , "Fundamentals of Machine Design", 5th Edition, Wiley India, 2011.
2	J A Collins, H Busby and G Stabb, "Mechanical Design of Machine Elements and Machines: A failure prevention perspective", 2nd Edition, Wiley India, 2009.
3	T H Courney, "Mechanical Behaviour of Materials", 2nd Edition, McGraw-Hill / Overseas Press India, 2000.
5	www.nptel.ac.in
6	http://ocw.mit.edu

Maintenance and Reliability	
Course Code: BMA-408	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: This course is designed to introduce basic concepts of maintenance and reliability to the students, to introduce various methods of reliability analysis and thus to make understanding the applications of Reliability and maintenance in a different type of systems.

Course Objectives: The objectives of this course are

- To apply knowledge to prevent or reduce the likelihood or frequency of failures
- To determine the correct cause of failures
- To determine the techniques of maintenance

Pre-Requisites: Operations Research

Course Outcomes: After successful completion of the course, the students will have -

CO1: Knowledge of reliability techniques to prevent failures
CO2: Evaluation of the causes of failures
CO3: Analysis of factors affecting maintainability
CO4: Understanding of the industrial approach towards availability and cost

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction to Reliability Availability and Maintainability (RAM), Development of RAM Engineering, Reliability Availability and Maintainability utilization factors, down time consequences. Reliability engineering fundamentals and applications, Historical perspectives,	
UNIT II	11 Hours
Reliability assessment, the relationship between different Reliability functions, typical Hazard functions, Mean time to failure, Cumulative Hazard function and average failure rate, Life testing. Application of Probability distribution function in Reliability evaluation combinational Aspects of Reliability	
UNIT III	10 Hours
Definition and application of Maintainability Engineering, Factors affecting Maintainability. Maintainability design criteria, operating and downtime categories, Maintainability and its quantification, Mean time to activity restore equipment, Mean Maintenance man-hours, Meantime for corrective and Preventive Maintenance	
UNIT IV	10 Hours
Maintenance, Replacement Policies. Availability, types of Availability, approaches to increase equipment Availability, Industrial approach towards mailability and cost.	

Text Books	
1	K.K. Aggarwal, "Reliability Engineering", 1st Edition, Springer Science & Business Media, 2006.
2	A. K. Govil, "Reliability Engineering", 1st Edition, Tata Mc-Graw-Hill Publishing Company, 1983.
3	Ebeling, "An Introduction to Reliability & Maintenance Engineering", 1st Edition, Mc-Graw Hill, 2006.
Reference Books	
1	Matthew P. Stephens, "Productivity and Reliability-Based Maintenance Management", 1st Edition, Purdue University Press, 2010.
2	Emery Roe and Paul R. Schulman, "High Reliability Management: Operating on the Edge", Stanford University Press, 2008.
3	Ramesh Gulati and Ricky Smith,"Maintenance and Reliability Best Practices", Industrial

	Press Inc., 2009.
5	www.nptel.ac.in
6	http://ocw.mit.edu

Reverse Engineering and Rapid Prototyping	
Course Code: BMA-410	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: The term rapid prototyping (RP) refers to a class of technologies that are used to produce physical objects layer-by-layer directly from computer-aided design (CAD) data. These techniques allow designers to produce tangible prototypes of their designs quickly, rather than just two-dimensional pictures. This course introduces advanced manufacturing technologies that are affecting contemporary design for manufacture (DFM) practices. It also describesa class of 3D printing and rapid prototyping (RP) technologies for rapid product development, including reverseengineering,3D printing and additive manufacturing, and rapid tooling and provides a holistic view of various applications of these technologies in relevant fields.

Course Objectives: The objectives of this course are

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

Pre-Requisites: NIL

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Knowledge about the basic principle of RP process.
CO2: Describe different RP techniques.
CO3: Discuss fundamentals of Reverse Engineering.
CO4: Evaluation of the accuracy issues in RP.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Review of solid modeling techniques with comparison advantages and disadvantages. Basic principle of RP processes, classification of RP processes, various Industrial RP systems like Sterolithography, Fused Deposition Modeling, Selective Laser Sintering, Laminated object Manufacturing, 3 D Printing.	
UNIT II	11 Hours
Role of Rapid Prototyping and Rapid Tooling in product development and simultaneous engineering. Process planning for rapid prototyping, STL file generation, defects in STL files, slicing procedure, Accuracy issues in Rapid Prototyping, Strength of RP parts, Surface roughness problem in RP.	
UNIT III	10 Hours
Part deposition orientation and issue like accuracy, surface finish, build time, support structure, cost etc. Rapid tooling technique such as laminated metallic tooling, direct metal laser sintering, vacuum casting	
UNIT IV	10 Hours
Introduction to reverse engineering. Selecting and optimally employing 3-D digitization strategies and systems. Efficiently using 3-D scanning, CAD model development for complex components and tools. Various CAD commands in modelling. Tools and equipment's available for scanning and their comparison, 3D White light scanning.	

Text Books	
1	Rafiq Noorani, "Rapid Prototyping: Principles and Application", John Wiley, Hoboken, 2006.
2	Kevin Otto and Kristin Wood, "Product Design: Technology in Reverse Engineering and New Product Development", Pearson, New Delhi, 2004.
3	Kai, Chua Chee, Fai Leong, "Rapid Prototyping: Principle & Application in Manufacturing",

	John Willey, London, 2003.
Reference Books	
1	Ian Gibson, Advanced Manufacturing Technology for Medical Applications: Reverse Engineering, Software Conversion and Rapid Prototyping, Willey, London, 2006.
2	Ali K. Kamrani, Emad Abouel Nasr, “Rapid Prototyping: Theory and Practice”, Volume 6 of Manufacturing Systems Engineering Series, Springer Science & Business Media, 2006.
3	G Bennett, “Rapid Prototyping Casebook”, Mechanical Engineering Publications, London, 1997.
5	www.nptel.ac.in
6	http://ocw.mit.edu

Non-conventional Manufacturing Processes	
Course Code: BMA-412	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: The course addresses the various alternative methods of manufacturing processes under the category of renewable sources. This would help students gain insight of the modern methods of manufacturing processes in industrial demand also.

Course Objectives: The objectives of this course are

- To get insight of problems associated with conventional sources of energy
- To teach various non-conventional methods
- To know the applications of the modern methods

Pre-Requisites: Manufacturing Processes

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Knowledge about the problems of conventional methods of manufacturing
CO2: Knowledge about various new manufacturing methods
CO3: Knowledge about implementation of processes
CO4: Understanding of the various types of machining

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction, Classification, their comparative study, Need. Process Selection: Physical Parameters, Shape applications, Material applications, Process capability, Effects on equipment and Tooling, Process economy.	
UNIT II	11 Hours
Ultrasonic Machining, Abrasive Jet Machining, Water Jet Machining and Abrasive Flow Machining considering their construction, working Principle, equipment used, process parameter, analysis, advantages, disadvantages and applications.	
UNIT III	10 Hours
Electro Chemical Machining (ECM), Electro Chemical Grinding (ECG), and Chemical Honing (ECH) considering their construction, working Principle, equipment used, process parameter, analysis, Advantages, Disadvantages and Applications	
UNIT IV	10 Hours
Laser Beam Machining, Electron Beam Machining, Electric Discharge Machining, Wire Cut EDM, Ion Beam Machining (IBM) and Plasma Arc Machining considering Working principle, equipment, Process parameters, Analysis, Advantages, Disadvantages and Application.	

Text Books	
1	P.C. Panday and H.S. Shan, “Modern Machining Process”, Tata McGraw-Hill Education, 1980.
2	Amitabh Gosh and A.K. Mallik, “Manufacturing Science”, Affiliated East-West Press Pvt. Ltd., 1985.
3	E. J. Weller, “Nontraditional Machining Process”, Society of Manufacturing Engineers, Publications/Marketing Division, 1984.
Reference Books	
1	G. F. Benedict, “Nontraditional Manufacturing Processes”, Marshal Dekkar, New York, 1987.
2	P. K. Mishra, “Nonconventional Machining”, Narosa Publications, 2007.
3	Vijay K Jain, “Advance Machining Processes”, Allied Publishers Pvt. Ltd., New Delhi, 2002.

5	www.nptel.ac.in
6	http://ocw.mit.edu

Product Design & Development	
Course Code: BMA-414	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: The product development through engineering aspects is always remains challenges to engineers. The aim of present course is to introduce the students about the basic product design process based on mechanical aspects applying innovative thinking and fundamentals of mechanical engineering.

Course Objectives: The objectives of this course are

- Competence with a set of tools and methods for product design and development.
- Confidence in your own abilities to create a new product.
- Awareness of the role of multiple functions in creating a new product (e.g. marketing, finance, industrial design, engineering, production).
- Ability to coordinate multiple, interdisciplinary tasks in order to achieve a common objective.
- Reinforcement of specific knowledge from other courses through practice and reflection in an action-oriented setting.
- Enhanced team working skills.

Pre-Requisites: NIL

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Knowledge of different concepts involved in product design and development cycle
CO2: Design some products for the given set of applications
CO3: Review product designs
CO4: Evaluation of the various concepts

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Product Design and Development: Introduction; product life cycle; product development process, sequential engineering, concurrent engineering. Concepts of concurrent engineering, quality of entire process. Product development organisation tools – total quality management; ISO 9000; reverse engineering; group technology etc. Market Identification – customer requirement and needs.	
UNIT II	11 Hours
Concept Generation and Evaluation of Concepts: Brain Storming; functional decomposition; morphological charts. Pugh's concept selection method; measurement scale; weighted decision matrix; AHP and MADM approaches. Concept testing.	
UNIT III	10 Hours
Preliminary/Embodiment Design: Product architecture. Configuration/form Design, Preliminary design for manufacture and assembly; materials and process selection. Industrial design. Prototyping.	
UNIT IV	10 Hours
Parametric and Detail Design: Design for X (Quality, Reliability, Maintainability, Serviceability, Environment, Recyclability, Safety, etc.) Improving details – value analysis and design for robustness, Design review; final detail design.	

Text Books	
1	Kari T.Ulrich and Steven D.Eppinger, "Product Design and Development", McGraw-Hill International Edns. 1999.
2	Boothroid et. al. "Product design for manufacturing & Assembly"; Marcel Dekker
3	Day, R.G. "Quality Function Deployment", Tata McGraw Hill.
Reference Books	

1	Staurt Pugh, “Tool Design -Integrated Methods for Successful Product Engineering”, Addison Wesley Publishing, New york, NY.
2	Ashby, M.F. “Material Design Method”, Pergamon Press, Oxford.
3	www.nptel.ac.in
4	http://ocw.mit.edu

Fracture Mechanics	
Course Code: BMA-418	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: The course will expose the student to fundamentals of linear elastic fracture mechanicsand fatigue crack growth. The student will learn about stress /strain and deformation fields near a crack tip, fracture characterizing parameters like stress intensity factor andJ integral and kinetics of fatigue crack growth.

Course Objectives: The objectives of this course are

- To introduce the mathematical and physical principles of fracture mechanics and their applications.
- Expand the students' knowledge on experimental methods to determine the fracture toughness.
- Develop the students understanding on the design principle of materials and structures using fracture mechanics approaches.

Pre-Requisites: Engineering Mechanics

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Correctly apply fracture mechanics to predict brittle fracture.

CO2: Identify the plane stress and plane strain conditions based on the shape and size of plastic zones and will correctly identify the cause of failure of a material based on fracture surface observations

CO3: Understand crack resistance and energy release rate for crack criticality.

CO4: Understand the relationship between crack tip opening displacement, SIF and ERR and application of such parameters for ductile and brittle materials

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction to Fracture Mechanics: Stress-Strain Curve, Elements of dislocation theory, Historical perspective, Stress Concentration effect of flaws, Fracture Mechanics approach to design, Effect of material properties on fracture, Cleavage, Brittle and Ductile fracture, ductile brittle transition, modes of fracture failure, Fatigue and stress corrosion cack growth, Damage tolerance.	
UNIT II	11 Hours
Linear Elastic Fracture Mechanics: An atomic view of fracture, Griffith Energy Balance, Energy release rate, instability and the R Curves, compliance, tearing modulus, Stress and Displacement field in isotropic elastic materials, Airy stress function, Westergard approach for different modes of fracture, Stress analysis of crack, Stress intensity factor (SIF), relation between K and global behaviour, Effect of finite size. **Elastic-Plastic Fracture Mechanics:** Crack tip deformation and plastic zone size, plane stress vs plane strain, effective crack length, Irwin plastic zone correction, Dugdale approach, effect of plate thickness	
UNIT III	10 Hours
J Contour Integral: Relevance and scope, J as a path-independent line integral, J as a stress intensity parameter, Stress-Strain relations, J-Controlled fracture, Laboratory measurement of J, Crack Tip Opening Displacement (CTOD), Relationship between CTOD, K and G, Equivalence between CTOD	

and J, Determination CTOD from strip yield model, HRR Singularity. **Fatigue Fracture:** Introduction to fatigue, factors affecting fatigue performance, fatigue loading, constant and variable amplitude loading, some characteristics of fatigue crack, Paris Law	
UNIT IV	10 Hours
Experimental and Finite Element Estimates of Fracture Mechanics: Experimental determination of J-Integral, Critical Stress intensity factor and CTOD, Photoelasticity techniques, strain gage measurements, Fatigue crack initiation and propagation testing. Pre-processing in Finite Element Method, Element selection and meshing of crack, Load application, constraints, pre-processing checks, processing the model, postprocessing	

Text Books	
1	Ted L. Anderson, T. L. Anderson, "Fracture Mechanics: Fundamentals and Applications", 3rd Edition, CRC Press, 2005.
2	Borek D., "Elementary Engineering Fracture Mechanics", 1st Edition, Springer, 2012.
3	Prashant Kumar, "elements of fracture mechanics", 1stEdition, McGraw Hill Education, 2017.
4	E. E. Gdoutos, "Fracture Mechanics: An Introduction", 2nd Edition, Springer, 2005.
Reference Books	
1	David Roylance, "Introduction to Fracture Mechanics", 1st Edition, MIT, 2001.
2	Surjya Kumar Maiti, "Fracture Mechanics: Fundamentals and Applications", 1st Edition, Cambridge University Press, 2015.
3	Naman Recho, "Fracture Mechanics and Crack Growth", 1st Edition, Wiley, 2013.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Non-Conventional Energy Resources	
Course Code: BMA-420	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: This course is an introductory course that covers the basics of the Non-Conventional Sources of energy like Solar, Wind, Biomass, Biogas, Tidal and Wave, Geothermal and Ocean. The students learn the ways that are used to harness the energies from the different sources described above.

Course Objectives: The objectives of this course are

- To make the students aware of different types of sources of energy
- To introduce the students to different ways that are used to harness different types of energy
- To make the student aware of the need of non-conventional sources of energy.

Pre-Requisites: Mathematics, Thermodynamics

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

CO1: Recognize the need of non-conventional energy sources.

CO2: Describe the working principle of wind energy conversion systems and understand the biogas and biomass energy conversion systems.

CO3: Describe various solar thermal energy conversion systems and understand the basics of solar photovoltaic systems.

CO4: Describe the ocean energy conversion systems

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction to various sources of energy; Solar thermal, Photovoltaic, hydro power, Wind energy, Biomass, Ocean thermal, Tidal and wave energy, Geothermal energy. **Solar Radiations:** Extra-terrestrial radiation, Spectral distribution, Solar constant, Solar radiations on earth, Measurement of solar radiations, Declination angle, Surface azimuth angle, Hour angle, Zenith angle, Local apparent time, Apparent motion of sun, Day length, Solar radiation data for India. **Solar Energy:** Solar thermal power and it's conversion, solar collectors, flat plate, performance analysis of flat plate collector, solar concentrating collectors, types of concentrating collectors, thermal analysis of solar collectors. Solar thermal energy storage, different systems and their applications, water heating, space heating & cooling, solar distillation, solar pumping, solar cooking, greenhouses, solar power plants.	
UNIT II	11 Hours
Solar Photovoltaic System: Photovoltaic effect, efficiency of solar cells, semiconductor materials for solar cells, solar photovoltaic system, standards of solar photovoltaic system, applications of PV system, PV hybrid system. **Biogas:** Photosynthesis, biogas production aerobic and anaerobic bio-conversion process, properties of biogas (composition and calorific value), storage and enrichment, community biogas plants, problems involved in bio gas production, bio gas applications, **Biomass:** generation, characterization, use as energy source, biomass conversion techniques, biomass cogeneration, fuel properties, biomass resource development in India.	
UNIT III	10 Hours
Wind Energy: Properties of wind, availability of wind energy in India, wind velocity, wind machine fundamentals, types of wind machines and their characteristics, horizontal and vertical axis windmills, elementary design principles, selection of a wind mill, wind energy farms, economic issues, and recent	

development. **Tidal and Wave Power:** Tides and waves as sources of energy, fundamentals of tidal power, use of tidal energy, limitations of tidal energy conversion systems.	
UNIT IV	10 Hours
Geothermal Energy: Structure of earth's interior, geothermal sites, geothermal resources, hot springs, steam system, types of geothermal station with schematic representation, site selection for geothermal power plants, problems associated with geothermal conversion. **Ocean Energy:** Principle of ocean thermal energy conversion, wave energy conversion machines, power plants based on ocean energy, problems associated with ocean thermal energy conversion systems, thermoelectric OTEC.	

Text Books	
1	G.D Rai, "Non-Conventional Energy Sources", 1st Edition, Khanna Publishers, 2011.
2	G.N. Tiwari and M.K. Ghosal, "Renewable Energy Resources: Basic Principles and Applications", 1st Edition, Alpha Science International, 2005.
3	John Twideu and Tony Weir, "Renewal Energy Resources" Routledge Publishers, 3rd edition, 2015.
Reference Books	
1	D.P. Kothari, K.C. Singal and Rakesh Ranjan, "Renewable Energy Resources and Emerging Technologies", 2nd Edition, Prentice Hall India Pvt. Ltd, 2011.
2	Duffie, J. A. & W. A. Beckman, "Solar Engineering of Thermal Processes", 4th Edition John Wiley & Sons, Inc., 2013
3	C. S. Solanki, "Solar Photovoltaics: Fundamental Applications and Technologies", 3rd Edition, Prentice Hall of India, 2013.
5	www.nptel.ac.in
6	http://ocw.mit.edu

Cogeneration and Improved Power cycles	
Course Code: BMA-422	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: This course is in continuation to power cycles students studied in their course of basic thermodynamics. It introduces the concepts of advanced power plant cycles, cogeneration systems and combination of power cycles along with the working and types of Nuclear Power Plants.

Course Objectives: The objectives of this course are

- Make the student aware of advanced power cycles
- Impart the knowledge of Combined power cycles to the students.
- To introduce students to the working of Nuclear Power Plants.

Pre-Requisites: Thermodynamics

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Analyse and evaluate the performance of single & combined Rankine cycle & efficiency enhancementtechniques

CO2: Explain the working principles of Hydroelectric Power Plant with calculation regarding the energyconversion in water turbines.

CO3: Explain the working principles of various components of steam generators, condensers and feed watersystem in a thermal power plant

CO4: Understand the mechanism of nuclear fission reaction and working principles of various Nuclear Power Plants

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Analysis of Steam cycles: Rankine cycle, Carnot cycle, effect of variation of steam condition on plant thermal efficiency, reheating of steam, regeneration, regenerative feed water heating, Carnotization of Rankine cycle, optimum degree of regeneration, Supercritical pressure cycle, Deaerator, typical layout and efficiencies of a steam power plant, Cogeneration of Power and Process Heat, Numerical Problems.	
UNIT II	11 Hours
Cogeneration systems: topping & bottoming cycles, Performance indices of cogeneration systems, Heat to power ratio, Thermodynamic performance of steam turbine cogeneration systems, gas turbine cogeneration systems	
UNIT III	10 Hours
Reciprocating IC engines cogeneration systems: Binary Cycle, Combined cycle – IGCC – AFBC / PFBC cycles, Thermionic steam power plant. MHD, Open cycle and closed cycle- Hybrid MHD & steam power plants	
UNIT IV	10 Hours
Combined cycle power generation: Flaws of steam as working fluid in Power Cycle, Characteristics of ideal working fluid, Binary vapor cycles, combined cycle plants, gas turbine-steam turbine power plant, MHD-steam power plant, Thermionic-Steam power plant.	

Text Books	
1	P K Nag, "Power Plant Engineering", 4th Edition, McGraw Hill Education, 2017.
2	Arora and Domkundwar, "Power Plant Engineering", 8th Edition, Dhanpat Rai Publication, 2016.

3	Haywood R.W, "Analysis of Engineering Cycles Power: Refrigeration and Gas Liquefaction", 4th Edition, Pergamon Press, 1991.
Reference Books	
1	John R. Lamarsh, Anthony J. Baratta , "Introduction to Nuclear Engineering", 3rd Edition, Pearson Education Limited, 2013.
2	A B Gill, "Power Plant Performance", 1st Edition, Standards media, 2003.
3	J P Horlock, "Cogeneration-combined heat and power (CHP): thermodynamics and economics", 1st Edition, Oxford, 1991.
4	www.nptel.ac.in
5	http://ocw.mit.edu

MEMS & NEMS	
Course Code: BMA-424	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: This course will introduce the fundamental basis of MEMS (Microelectromechanical Systems) and NEMS (Nanoelectromechanical Systems) including design, analysis, fabrication, integration, packaging and testing. In addition, this course will also introduce the most recent development of micro-/nano- fabrication technologies, and up-to-date applications of MEMS and NEMS as well.

Course Objectives: The objectives of this course are

- To introduce the concepts of micro and nano electromechanical devices
- To know the fabrication process of Microsystems
- To know the design concepts of micro sensors and micro actuators
- To introduce the concepts of quantum mechanics and nano systems

Pre-Requisites: Basic understanding of MEMS and NEMS technologies

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Knowledge about the basics of micro/nano electromechanical systems including their applications and advantages.
CO2: Recognize the use of materials in micro fabrication and describe the fabrication processes
CO3: Analyze the key performance aspects of electromechanical transducers
CO4: Knowledge about the synthesis and fabrication of mems

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
NANO-AND MICROSCIENCE, ENGINEERING AND TECHNOLOGY: Introduction and overview, MEMS and NEMS definitions, Taxonamy of Nano-and Microsystems, Materials used for synthesis and Design of MEMS and NEMS.	
UNIT II	11 Hours
NANO-AND MICRO SYSTEMS: Classification and considerations, Biomimetics, Biological analogies, and design–Biomimetics Fundamentals, Biomimetics for NEMS and MEMS, Nano-ICs and Nanocomputer architectures, Biomimetics and nervous systems.	
UNIT III	10 Hours
MODELING OF MICRO-AND NANOSCALE ELECTROMECHANICAL SYSTEMS: Introduction to modeling, analysis and simulation, basic electro-magnetic with application to MEMS and NEMS, modeling developments of micro-and nanoactuators, energy conversion in NEMS and MEMS.	
UNIT IV	10 Hours
SYNTHESIS, DESIGN AND FABRICATION OF MEMS: Introduction, Deposition of multilayers, Microfabrication of microcoils / windings of copper, nickel and aluminium through electrodeposition method, micromachined polymer magnets, axial electromagnetic micromotors, micromachined polycrystalline SiC microimotors.	

Text Books	
1	Lyshevski, Sergey Edward. “Nano-and micro-electromechanical systems: fundamentals of nano-and microengineering”, 1st Edition, CRC press, 2018.
2	A. S.Edelstein and R.C.Cammarata. “Nanomaterials:Synthesis,Properties and Applications”,2nd Edition, Institute of Physics, 1998.
3	Stephen D. Senturia, “Micro system Design”, 1st Edition, Kluwer Academic Publishers,2005
Reference Books	

1	Chang Liu, “Foundations of MEMS”, 2nd Edition, Pearson education India limited, 2011.
2	Tai Ran Hsu, “MEMS and Microsystems: Design and Manufacture”, 1st Edition, Tata Mcraw Hill, 2017
3	Marc Madou, “Fundamentals of Microfabrication”, 3rd Edition, CRC press, 2011.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Design of Experiments	
Course Code: BMA-426	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: Design of Experiments (DOE) is a methodology that can be effective for general problem solving, as well as for improving or optimizing product design and manufacturing processes. Specific applications of DOE include, but are not limited to, identifying root causes to quality or production problems, identifying optimized design and process settings, achieving robust designs, and generating predictive math models that describe physical system behaviour.

Course Objectives: The objectives of this course are

- To impart knowledge on various types of experimental designs
- To impart knowledge conduct of experiments and
- To impart knowledge data analysis techniques.

Pre-Requisites: NIL

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Valuate the suitability of the models treated in the course, for different experimental situations
CO2: Analyse experimental data
CO3: Plan and conduct smaller experiments within given time frames
CO4: Present the planning, implementation, and analysis of a conducted experiment

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction: Introduction, Need for Research, Need for Design of Experiments, Experimental Design Techniques, Applications of Experimental Design, Marketing, Production, Finance, Personnel	
UNIT II	11 Hours
Analysis of Variance: Introduction, Test of Hypothesis, Tests of Hypotheses Concerning Mean(s), Two Tailed Test Concerning Difference between Two Means when the Variances of the Populations are Known, Two Tailed Test Concerning Difference between Two Means When the Variances of the Populations are Unknown and the Sample Sizes are Small.	
UNIT III	10 Hours
Simple Designs of ANOVA: Limitations of Testing of Hypothesis for Difference between the Means, Using F-Test, F-Distribution, Two Tailed F-Test, Introduction and Need for Analysis of Variance (ANOVA)Completely Randomized Design, Randomized Complete Block Design, Latin Square Design, Duncan's Multiple Range Test, Case Study	
UNIT IV	10 Hours
Complete Factorial Experiment: Introduction, Two-Factor Complete Factorial Experiment, Complete Factorial Experiment with Three Factors, 2^n Factorial Experiment, Concept of 2^2 Factorial Experiment, Concept of 2^3 Design, Yates' Algorithm for 2^nFactorial Experiment, 3^nFactorial Experiment, Concept of 3^2 Factorial Experiment.	

Text Books	
1	Douglas C. Montgomery, "Design and Analysis of Experiments", 10th Edition John Wiley and sons, 2019.
2	Mead, R., "The design of experiments: statistical principles for practical applications". 1st Edition, Cambridge university press, 1990.

3	Anderson, V. L., & McLean, R. A.,"Design of experiments: a realistic approach. Routledge", 1st Edition, CRC Press, 2019.
4	Krishnaiah K, and Shahabudeen P, "Applied Design of Experiments and Taguchi Methods", 1st Edition, PHI, India, 2012.
5	Phillip J. Ross, "Taguchi Techniques for Quality Engineering", 2nd Edition, Tata McGraw-Hill, India, 2005.
Reference Books	
1	Angela M. Dean and Daniel Voss. "Design and Analysis of Experiments", 2nd Edition, Springer, NY, 2017.
2	Jiju Antony,"Design of Experiments for Engineers and Scientists". 2nd Edition, Butterworth-Heinemann, 2018.
3	Hines and Montgomery, "Probability and Statistics for Engineers", 4th Edition, John Wiley and Sons, NY, 2012.
4	Barton, R. R.,"Graphical methods for the design of experiments (Vol. 143)". Springer Science & Business Media, 1999.
5	Mathews, P. G.,"Design of Experiments with MINITAB". 1st Edition, ASQ Quality Press, 2010.
6	www.nptel.ac.in
7	http://ocw.mit.edu

Sensors and Actuators	
Course Code: BMA-428	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: This course is designed with an aim of educating students in microtechnology and its use to fabricate sensors and systems. The students will have an exposure to sensors and its importance in the real world. The students will also be able to understand how to fabricate some of those sensors. They will have an exposure towards how to fabricate the sensors and its application in real world and understand and also learn modern day microsensors and micro actuators, how to simulate some of those sensors and characterise before fabricating it.

Course Objectives: The objectives of this course are

- To learn the basic concepts of sensors and actuators.
- To learn the different types of sensors and actuators.
- To learn designing and fabrication of sensors and actuators.

Pre-Requisites: Basic knowledge of sensors and actuators

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Understanding the basics of Sensors and actuators.
CO2: Evaluation of thin film deposition techniques.
CO3: Knowledge about various gas sensors
CO4: Design and fabricate various microsensors and simulate and optimize sensors and actuators.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers,projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	10Hours
Introduction: Basics of Energy Transformation: Transducers, Sensors and Actuators, Understanding of thin filmphysics: Application in MOSFET and its variants.	
UNIT II	11 Hours
Thin Film Deposition Techniques: Chemical Vapor Deposition, Physical Vapor Deposition (Thermal Deposition, E-beam Evaporation, Sputtering, Pulsed Laser Deposition), Basic understanding of Photolithography for pattering layer. Detailed overview of Etching methods.	
UNIT III	10 Hours
Understanding various gas sensors: Optical gas sensor, Metal oxide semiconductor gas sensor, Field effect transistor gas sensor, Piezoelectric gas sensor, Polymer gas sensor, Nano-structured based gas sensors	
UNIT IV	11 Hours
Design and fabrication process of Microsensors: Force Sensors, Pressure Sensors, Strain gauges and practical applications, Explain working principlesof Actuators. Piezoelectric and Piezoresistive actuators, micropumps and micro actuators with practical applications, Simulation, Optimization and characterization of various sensors, Understanding of Sensor Interfacing with Microprocessor	

Text Books	
1	Ramón Pallás-Areny, John G. Webster, “Sensors and Signal Conditioning”, Wiley Blackwell, 2nd Edition, 2012.

2	Stefan Johann Rupitsch, “Piezoelectric Sensors and Actuators”, 1st Edition, Fundamentals and Applications, Springer, 2018
3	Stephen D. Senturia, “Microsystem Design”, 1st Edition, Kluwer Academic Publisher, 2005
Reference Books	
1	Simon Sze, “VLSI Technology”, 2nd Edition, McGraw Hill, 1988 Madou
2	Marc J Madou, “M Fundamentals of Microfabrication”, 3rd Edition, CRC Press, 2011.
3.	J.D. Plummer, M.D. Deal, P.G. Griffin, “Silicon VLSI Technology: Fundamentals, Practice and Modeling”, 1st edition, Pearson, 2010.
4	www.nptel.ac.in

Jet Propulsion Systems	
Course Code: BMA-430	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 7
Course Category: DEC	

Introduction: This course presents aerospace propulsive devices as systems, with functional requirements and engineering and environmental limitations along with requirements and limitations that constrain design choices. Both air-breathing and rocket engines are covered, at a level which enables rational integration of the propulsive system into an overall vehicle design. Mission analysis, fundamental performance relations, and exemplary design solutions are presented.

Course Objectives: The objectives of this course are

- List and explain the characteristics and performance of aerospace propulsion systems.
- Model newly conceived rocket or air breathing propulsion systems and estimate their performance and behaviour.
- Carry out preliminary designs of rocket or air breathing propulsion systems to meet specified requirements.

Pre-Requisites: Thermodynamics, Fluid Dynamics, Heat Transfer

Course Outcomes: After successful completion of the course, the students will be able to -

CO1: Explain the different features and capabilities of chemical and non-chemical rocket propulsion systems.

CO2: Estimate the specific impulse and mass flow for a rocket engine accounting for chemical reaction and non-constant specific heats gas with constant specific heats.

CO3: Explain the causes of, and estimate, the stress on rocket casings, turbo-machine blades, and blade disks in turbo-machines and calculate pressure and temperature changes across the turbo-machinery, inlet, and exhaust nozzle in a gas turbine engine from a knowledge of the geometry.

CO4: Explain the limits imposed on gas turbine engine design by environmental restrictions

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Basic concepts: Energy and momentum equations of compressible fluid flows, Stagnation states, Mach waves and Mach cone, Effect of Mach number on compressibility. **Isentropic Flow:** Nozzle and Diffusers, compressors and turbines, Use of Gas tables. **Isentropic Flow:** Isentropic flow through variable area ducts.	
UNIT II	11 Hours
Flow through ducts: Flow through constant area ducts with heat transfer (Rayleigh flow) and Friction (Fanno flow), Variation of flow properties,use of tables and charts, Generalized gas dynamics. **Normal and oblique shocks:** Governing equations, Variation of flow parameters across the normal and oblique shocks, Prandtl Meyer relations, Expansion of supersonic flow, Use of table and charts, Applications.	

UNIT III	10 Hours
Jet propulsion: Theory of jet propulsion, thrust equation,thrust power and propulsive efficiency, Operation principle, cycle analysis and use of stagnation state performance of ram jet, turbojet, turbofan and turbo-prop engines, Aircraft combustors.	
UNIT IV	10 Hours
Space propulsion: Types of rocket engines – Propellants – Ignition and combustion – Theory of rocket propulsion – Performance study – Staging – Terminal and characteristic velocity – Applications – Space flights.	

Textbooks	
1	Cohen H., Rogers G. E. and Saravanamuttoo,"Gas Turbine Theory", 7th Edition, Pearson, 2019.
2	Kroes Michael J, Wild Thomas W,"Aircraft Powerplants",8th Edition, Tata-McGraw-Hill, 2017.
3	Hill Philip, Peterson Carl, "Mechanics and Thermodynamics of Propulsion", 2ndEdition, Addison Wesly, 2009.
Reference Books	
1	Mattingly J D, Boyer Keith, "Elements of Propulsion - Gas Turbines and Rockets", 2nd Edition, AIAA Education series, 2017.
2	El-Sayed Ahmed, "Aircraft Propulsion and gas Turbine Engines", 2nd Edition, Taylor and Francis (CRC press), 2017
3	Shapiro A. H. "Dynamics and Thermodynamics of Compressible Fluid Flow – Vol.I", 1st Edition, John Wiley, New York – 1953
5	www.nptel.ac.in
6	http://ocw.mit.edu