NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

M.TECH – Computer Integrated Manufacturing

SCHEME OF INSTRUCTION AND SYLLABI

for M.Tech. Programme in Computer Integrated Manufacturing

(Effective from 2021-22)

DEPARTMENT OF MECHANICAL ENGINEERING

Vision and Mission of the Institute

National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society.

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

DEPARTMENT OF MECHANICAL ENGINEERING

VISION

To be a global knowledge hub in mechanical engineering education, research, entrepreneurship, and industry outreach services.

MISSION

- Impart quality education and training to nurture globally competitive mechanical engineers.
- Provide vital state-of-the-art research facilities to create, interpret, apply and disseminate knowledge.
- Develop linkages with world class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.

Department of Mechanical Engineering:

Brief about the Department:

The Department of Mechanical Engineering was established in the year 1959. The department presently offers one Under Graduate Programme, i.e., B.Tech in Mechanical Engineering with an intake of 170 students, seven M.Tech programs - Thermal Engineering, Manufacturing Engineering, Computer Integrated Manufacturing, Machine Design, Automobile Engineering, Materials and Systems Engineering Design, Additive Manufacturing – one PG Diploma in Additive Manufacturing and Ph.D. programs. At present, the Department has 48 faculty members with research expertise in different specializations of Mechanical Engineering. The Department has good research facilities for both experimental as well as simulation-based research. The department has liaison with reputed industries and R&D organizations such as NFTDC, DMRL, DRDL, ARCI, BHEL, CPRI, CMTI, etc. All the faculty of the department are actively engaged in R&D and Consultancy. Presently the department is handling about 25 funded projects worth Rs. 3.00 Crores. The department has recently acquired Metal 3D Printer at a cost of Rs.1.4 Crores under TEQIP -III grants. The institute is establishing SIEMENS Centre of Excellence in Digital Manufacturing and Industry 4.o in which the department is playing a key role. The department produces a large number of publications, and offers solutions to the industry regularly and is also active with regular outreach activities like workshops, conferences and executive programs for industry personnel. The department has been recognized as QIP Centre for M.Tech and Ph. D. programmes.

List of Programs offered by the Department:

Program	Title of the Program
B.Tech.	Mechanical Engineering
M.Tech.	Thermal Engineering
	Automobile Engineering
	Manufacturing Engineering
	Machine Design
	Computer Integrated Manufacturing
	Materials and Systems Engineering Design
	Additive Manufacturing
PG-Diploma	Additive Manufacturing
Ph.D.	Mechanical Engineering

Note: Refer to the following weblink for Rules and Regulations of M.Tech. program:
https://www.nitw.ac.in/main/MTechProgram/rulesandregulations/

M.Tech. – Computer Integrated Manufacturing

Programme Educational Objectives:

Programme Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the programme is preparing graduates to achieve. They are consistent with the mission of the Institution and Department. Department faculty members continuously worked with stakeholders (local employers, industry and R&D advisors and the alumni) to review and update them periodically.

PEO1	Design and develop computer integrated manufacturing systems using the knowledge of mathematics, science, engineering, and IT tools.
PEO2	Apply modern computational, analytical, simulation tools and techniques to face the challenges in manufacturing and its integration.
PEO3	Apply management principles to execute projects of inter-disciplinary nature adhering to professional ethics
PEO4	Engage in life-long learning to adapt to the changing needs for professional Advancement

Program Articulation Matrix

PEO / **Mission Statements**	**PEO1**	**PEO2**	**PEO3**	**PEO4**
Impart quality education and training to nurture globally competitive mechanical engineers.	3	3	3	2
Provide vital state of the art research facilities to create, interpret, apply and disseminate knowledge.	3	2	3	3
Develop linkages with world-class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.	3	2	3	2

1: Slightly **2: Moderately** **3: Substantially**

M.Tech – Computer Integrated Manufacturing

Programme Outcomes (POs) are narrower statements that describe what the students are expected to know and be able to do upon the graduation. They relate the knowledge, skills and behaviour of the students acquire through the program. The POs are specific to the programme and facilitate the attainment of PEOs.

At the end of the programme the student shall be able to:

PO1	Carryout independent research/investigation and development work to solve practical problems.
PO2	Write and present a substantial technical report/document.
PO3	Demonstrate a degree of mastery in computer integrated manufacturing at a level higher than the Bachelor's programme.
PO4	Apply engineering knowledge, techniques, and modern tools to design, simulate and analyze computer integrated manufacturing systems.
PO5	Develop management control systems for production planning, logistics and service using CAD, CAM and Mechatronics techniques.
PO6	Engage in lifelong learning adhering to professional, ethical, legal, safety, environmental and societal aspects for career excellence.

MAPPING OF PROGRAM OUTCOMES WITH PROGRAM EDUCATIONAL OBJECTIVES:

PEO	PO1	PO2	PO3	PO4	PO5	PO6
PEO 1	3	3	3	3	2	3
PEO 2	3	3	3	3	3	2
PEO 3	2	2	2	2	2	3
PEO 4	2	2	2	2	2	3

Credits in Each Semester

Category	**I Year, Sem – I**	**I Year, Sem – II**	**II Year, Sem – I**	**II Year, Sem – II**	**Total No. of credits to be earned**
Core Courses	12	06	--	--	**18**
Electives	06	12	--	--	**18**
Lab Courses	04	04	--	--	**08**
Comprehensive Viva-Voce	--	--	02	--	**02**
Seminar	01	01	--	--	**02**
Dissertation	--	--	12	20	**32**
Total	**23**	**23**	**14**	**20**	**80**

SCHEME OF INSTRUCTION AND EVALUATION

M.Tech. (Computer Integrated Manufacturing) Course Structure

I – Year: I – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	ME5301	Integrated Production Control Systems	3	0	0	3	PCC
2	ME5302	Mechatronics and MEMS	3	0	0	3	PCC
3	ME5203	CNC and AM Technologies	3	0	0	3	PCC
4	ME5204	Advanced CAD	3	0	0	3	PCC
5		Elective – I	3	0	0	3	PEC
6		Elective – II	3	0	0	3	PEC
7	ME5305	Mechatronics and Automation Laboratory	0	1	2	2	PCC
8	ME5206	CAE Laboratory	0	1	2	2	PCC
9	ME5348	Seminar – I	0	0	2	1	SEM
		Total	**18**	**2**	**7**	**23**	

PCC – Program Core Course; PEC: Program Elective Course

I – Year: II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	ME5351	Systems Approach to CIM	3	0	0	3	PCC
2	ME5352	Factory Automation	3	0	0	3	PCC
3		Elective – III	3	0	0	3	PEC
4		Elective – IV	3	0	0	3	PEC
5		Elective – V	3	0	0	3	PEC
6		Elective – VI	3	0	0	3	PEC
7	ME5353	Manufacturing Simulation Laboratory	0	1	2	2	PCC
8	ME5354	CNC and AM Laboratory	0	1	2	2	PCC
9	ME5398	Seminar – II	0	0	2	1	SEM
		Total	**18**	**2**	**7**	**23**	

II – Year: I – Semester

S. No.	Course Code	Course Title	Credits	Cat. Code
1	ME6347	Comprehensive Viva-voce	2	CVV
2	ME6349	Dissertation Part-A	12	DW
		Total	**14**	

II – Year: II – Semester

S. No	Course Code	Course Title	Credits	Cat. Code
1	ME6399	Dissertation Part-B	20	DW
		Total	**20**	

LIST OF ELECTIVES

I Year, I Semester

S. No.	Course Code	Course Title	L-T-P	Credits	Cat. Code
Program Specific Professional Elective Courses					
1	ME5311	Enterprise Resource Planning	3-0-0	3	PEC
2	ME5312	Manufacturing Management	3-0-0	3	PEC
3	ME5313	Soft Computing Techniques	3-0-0	3	PEC
Elective Courses from M.Tech Manufacturing Engineering					
1	ME5211	Micro and Nano Manufacturing	3-0-0	3	PEC
2	ME5212	Metrology and Computer Aided Inspection	3-0-0	3	PEC
Elective Courses from M.Tech MSED					
1	ME5613	Mechanics of Metal Forming	3-0-0	3	PEC
Elective Courses from M.Tech Additive Manufacturing					
1	ME5712	3D Printing	3-0-0	3	PEC
Elective Courses from M.Tech Thermal Engineering					
1	ME5102	Computational Methods in Thermal Engineering	3-0-0	3	PEC
2	ME5113	Renewable Sources of Energy	3-0-0	3	PEC
3	ME5114	Energy Systems and Management	3-0-0	3	PEC
Elective Courses from M.Tech Machine Design					
1	ME5415	Mathematical Methods in Engineering	3-0-0	3	PEC

List of Elective Courses (M.Tech – CIM)

I Year, II Semester

S. No.	Course Code	Course Title	L-T-P	Credits	Cat. Code
Program Specific Elective Courses					
1	ME5361	Supply Chain Management	3-0-0	3	PEC
2	ME5362	Modelling and Simulation of Manufacturing Systems	3-0-0	3	PEC
3	ME5363	Intelligent Manufacturing Systems	3-0-0	3	PEC
4	ME5364	Lean Manufacturing Systems	3-0-0	3	PEC
5	ME5365	Sustainable Manufacturing	3-0-0	3	PEC
6	ME5366	Product Life Cycle Management	3-0-0	3	PEC
7	ME5367	Reliability Engineering	3-0-0	3	PEC
8	ME5368	Industry 4.o and IIoT	3-0-0	3	PEC
9	ME5369	Design and Analysis of Experiments	3-0-0	3	PEC
10	ME5370	Project Management	3-0-0	3	PEC
11	ME5371	AI and ML for Mechanical Systems	3-0-0	3	PEC
Elective Courses from M.Tech Manufacturing Engineering					
1	ME5262	Product Design for Manufacturing and Assembly	3-0-0	3	PEC
2	ME5264	Geometric Dimensioning and Tolerancing	3-0-0	3	PEC
3	ME5265	Mechatronics and Robotics	3-0-0	3	PEC
4	ME5266	Precision Manufacturing	3-0-0	3	PEC
Elective Courses from M.Tech MSED					
1	ME5611	Surface Engineering	3-0-0	3	PEC
2	ME5664	Non-Destructive Testing and Evaluation	3-0-0	3	PEC
Elective Courses from M.Tech Additive Manufacturing					
1	ME5761	Additive Manufacturing in Medical Applications	3-0-0	3	PEC
2	ME5762	Powders for Additive Manufacturing	3-0-0	3	PEC
3	ME5763	Re-Engineering	3-0-0	3	PEC
4	ME5764	Metallurgy in Additive Manufacturing	3-0-0	3	PEC
Elective Courses from M.Tech Thermal Engineering					
1	ME5170	Essentials for Entrepreneurship	3-0-0	3	PEC
2	ME5173	Energy Conservation and Waste Heat Recovery	3-0-0	3	PEC
Elective Courses from M.Tech Machine Design					
1	ME5403	Mechanical Vibrations	3-0-0	3	PEC
2	ME5452	Finite Element Analysis in Design	3-0-0	3	PEC
3	ME5466	Tribology in Design	3-0-0	3	PEC
4	ME5467	Advanced Composite Technologies	3-0-0	3	PEC
5	ME5468	Robotics	3-0-0	3	PEC
6	ME5469	Optimization Methods for Engineering Design	3-0-0	3	PEC

DETAILED CORE COURSES SYLLABUS

M.Tech. – Computer Integrated Manufacturing

ME 5301	INTEGRATED PRODUCTION CONTROL SYSTEMS	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Identify competitive priorities and production planning & control strategies for production systems under various scenarios
CO2	Apply ROP and MRP techniques for planning and control of production systems.
CO3	Apply JIT philosophy for manufacturing systems
CO4	Design push and pull systems using the principles of factory dynamics.
CO5	Design factory systems for shop floor control, production scheduling, aggregate planning and capacity planning by considering SCM issues.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2		3	2
CO2	1		2	2	2	
CO3	2		2	2	3	
CO4	2		3	2	3	
CO5	2		3	2	3	

Syllabus:

Introduction: Competitive dimensions, order qualifiers & winners, manufacturing systems characterization, manufacturing strategy.

Inventory Control: EOQ, dynamic lot sizing, statistical inventory control models.

Materials Requirements Planning (MRP): Concept of dependent demand, structure of MRP system, MRP calculations, planning & implementation issues, MRP-II & ERP.

Just-In-Time (JIT) Manufacturing: Origin & goals, small lot production, stable MPS, kanban control, vendor participation, continuous improvement, strategic implications of JIT system.

Factory Dynamics: Little' law, concept of effective processing time, flow variability, blocking, influence of variability.

Push and Pull Control Systems: Concept of push and pull control, benefits of pull control, CONWIP & DBR systems.

Pull Planning Framework: Demand management, capacity planning, aggregate planning, Production scheduling, shop floor control, synthesis.

Supply Chain Management: Introduction to Supply Chain Management, Decision phases in a supply chain, Process views of a supply chain: push/pull and cycle views, Achieving Strategic fit, Expanding strategic scope.

Learning Resources

Text Books:

1. Operations Management: Strategy and Analysis, Krajewski U and Ritzman LP, Pearson Education Pvt. Ltd., Singapore, 2002.
2. Operations Management for Competitive Advantage, Chase RB, Aquilano NJ and Jacobs RF, McGraw-Hill Book Company, NY, 2005.
3. Factory Physics: Foundations of Manufacturing Management, Hopp WJ and Spearman ML, McGraw-Hill, NY,Third Edition , 2008.

Reference Books:

1. Supply Chain Management, Sunil Chopra, Peter Meindl, and D.V. Kalra, Pearson Education Pvt. Ltd., Singapore, 6th Editon, 2016.

Online Resources:

1. https://nptel.ac.in.

ME 5302	MECHATRONICS AND MEMS	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Generate conceptual design for Mechatronic systems based on potential customer requirements
CO2	Select appropriate sensors and transducers and devise an instrumentation system for collecting information about processes
CO3	Design a control system for effective functioning of Mechatronic systems using digital electronics, microprocessors, microcontrollers and programmable logic controllers
CO4	Evaluate the performance of a Mechatronic systems
CO5	Understand MEMS fabrication techniques

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2	2	3	
CO2	2		2	2	3	
CO3	3		3	3	3	
CO4	2		2	3	3	2
CO5	1		2	2	3	

Syllabus:

Historical perspective, Definition, Applications, Block diagram of Mechatronic system, Functions of Mechatronics Systems, Systems Engineering, Verification Vs Validation, Benefits of mechatronics in manufacturing.

Opto-Mechatronics: Historical perspective, Definition and Basic concept, Fundamental Functions of Opto-Mechatronics systems, Design Process, Opto-Mechatronics Technologies, Applications of Opto-Mechatronics systems.

Modelling, Analysis and Control of Physical Systems : Basics of System Modelling: LTI and LTV systems, Need for modelling, Types of modelling, Steps in modelling, Building blocks of models, Modelling of one and two degrees of freedom systems, Modelling of Electro-mechanical systems, Mechanical Systems, Fluid systems, Thermal systems; Dynamic Responses, System Transfer Functions, State Space Analysis and System Properties, Stability Analysis using Root Locus Method, Stability Analysis using Bode Plots, PID Controllers (with and without Time Delay).

Sensors and Actuators: Static characteristics of sensors and actuators, Position, Displacement and Proximity Sensors, Force and torque sensors, Pressure sensors, Flow sensors, Temperature sensors, Acceleration sensors, Level sensors, Light sensors, Smart material sensors, Micro and Nano sensors, Selection criteria for sensors.

Actuators: Electrical Actuators (Solenoids, Relays, Diodes, Thyristors, Triacs, BJT, FET, DC motor, Servo motor, BLDC motor, AC motor, Stepper motors), Hydraulic and Pneumatic actuators, Design of Hydraulic and Pneumatic circuits, Piezoelectric actuators, Shape memory alloys.

Microcontrollers and Programmable Logic Controllers: Logic Concepts and Design, System Interfaces, Communication and Computer Networks, Fault Analysis in Mechatronic Systems, Synchronous and Asynchronous Sequential Systems, Architecture, Microcontrollers, Programmable Logic Controllers (PLCs): Architecture, Number Systems Basics of PLC Programming, Logics, Timers and Counters, Application on real time industrial automation systems. Introduction to Arduino & Raspberry Pi, Pin configuration and architecture, Device and platform features. Concept of digital and analogy ports. Familiarizing with Arduino Interfacing Board

Micro-Electro Mechanical Systems (MEMS): History, Effect of scaling, Fabrication techniques: Oxidation, Sputter disposition, CVD, Lithography, Etching, Wafer bonding, LIGA, DRIE, Applications: Lab on chip

Case Studies: Design of pick and place robot, Car engine management system, Automated manufacturing system, Automatic camera, Automatic parking system, Safety devices and systems.

Learning Resources:

Text Books:

1. Mechatronics, Electronic control systems in mechanical and electrical engineering, W. Bolton, Pearson Education, 5/e, 2011.
2. Mechatronics Systems Design, Devadas Shetty, Cengage Learning, USA, 2012.
3. MEMS and Microsystems: Design and Manufacture, Tai-Ran Hsu, McGraw- Hill, 2008
4. Mechatronics: A foundation course, Clarence W. de Silva, CRC Press, 2010

References:

1. Micro Electro Mechanical Systems Design, James J Allen, CRC Press Taylor & Francis group, 2009.
2. The Mechatronics Handbook, Robert H. Bishop, CRC Press, 2/e, 2007.
3. Opto-Mechatronics systems Handbook, Frank Kreith, CRC Press, Taylor& Francis Group, 2010.

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc21_me129/preview (Course by Prof. PS Gandhi, IITB)
2. http://video_demos.colostate.edu/mechatronics
3. http://mechatronics.me.wisc.edu

ME5203	CNC AND AM TECHNOLOGIES	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Classify and distinguish NC, CNC and DNC systems.
CO2	Develop manual and APT part programs for machining of complex parts.
CO3	Design structures for CNC machines.
CO4	Develop interpolation algorithms for control loops.
CO5	Design and develop AM machines and their control strategies.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2	2	2	
CO2	2		2	2	2	
CO3	2		2	2	2	
CO4	2		2	3	2	
CO5	2		3	3	2	

Syllabus:

CNC Technology: An overview: Introduction, Classification, Advantage, Disadvantages and applications of NC/CNC/DNC and Machine Tool, product cycle and automation in CAD/CAM, Need of CAD/CAM, Computer Aided Process Planning (CAPP), Basic concepts of process planning.

Design Of CNC: Constructional features of CNC machine tools, Design at ion of axis in CNC systems, NC coordinate system, positional control, system devices; drives, ball screws, transducers, feedback devices

Part Programming: CNC programming and introduction, Manual part programming: Basic (Drilling, milling, turning etc...), Special part programming, Advanced part programming, APT programming, macros, fixed cycles.

Interpolators: Hardware Interpolators, Software Interpolators, NC/ CNC controllers.

Introduction to Additive Manufacturing: Introduction to AM and Advantages and Limitations, AM evolution, Difference between AM & CNC machining,

AM Process Chain: Conceptualization, CAD, conversion to STL, Transfer to AM, STL file manipulation, Machine setup, build, removal and clean up, post processing.

Construction of Basic AM Machines: Construction of AM machines - Axes, linear motion, guideways etc.

Learning Resources:

Text Books:

1. Computer Control of Manufacturing Systems, Yoram Koren, McGraw Hill International, Singapore, 2006
2. Computer Numerical Control: Operation and Programming, John Stenerson and Kelly Curran, PHI, New Delhi, 2009
3. Computer Aided Manufacturing, Tien - Chien Chang, Richard A Wysk and Hsu-Pin Wang, PHI, New Dellhi,2006
4. Rapid Prototyping: Principles & Applications", Chua Chee Kai, Leong Kah Fai, World Scientific, 2003.
5. Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing", Ian Gibson, David W Rosen, Brent Stucker., Springer, 2010
6. Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, D.T. Pham, S.S. Dimov, Springer 2001.

Reference Books:

1. Computer Control of Manufacturing Systems, YoramKoren, McGraw Hill International, Singapore,2006.
2. Computer Numerical Control: Operation andProgramming, John Stenerson and Kelly Curran, PHI, New Delhi, 2009.
3. Computer Aided Manufacturing, Tien-ChienChang, RichardAWyskandHsu-PinWang, PHI, NewDelhi, 2009.
4. Rapid Prototyping: Principles & Applications, Chua Chee Kai, Leong Kah Fai, World scientific,2003.
5. Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, IanGibson,DavidWRosen, Brent Stucker, Springer, 2010.
6. Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, D.T. Pham, S.S. Dimov, Springer 2001.

ME5204	ADVANCED CAD	3-0-0:3

PRE-REQUISITES: NIL

COURSE OUTCOMES: At the end of the course, the student shall be able to:

CO1	Understand conceptual design process and geometric transformation techniques in CAD.
CO2	Develop mathematical models to represent curves.
CO3	Design surface and solid models for engineering applications.
CO4	Apply CAD techniques for engineering analysis and geometry processing.

CO-PO Mapping**:**

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2		2		2	
CO2	2		2	2	2	
CO3	3		3	3	2	
CO4	3		2	2	2	
CO5	2		2	2	2	

Syllabus:

Introduction: Introduction to CAE, CAD. Role of CAD in Mechanical Engineering, Design process, software tools for CAD, Geometric modelling.

Transformations in Geometric Modelling: Introduction, Translation, Scaling, Reflection, Rotation in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations. Implementation of the transformations using computer codes.

Design of Curves: Analytic Curves, PC curve, Ferguson, Composite Ferguson, curve Trimming and Blending, Bezier segments, de Casteljau's algorithm, Bernstein polynomials, Bezier-subdivision, Degree elevation, Composite Bezier, Splines, Polynomial Splines, B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS, Developing algorithms/computer codes for Design of Curves.

Design of Surfaces: Differential geometry, Parametric representation, Curves on surface, Classification of points, Curvatures, Developable surfaces, Surfaces of revolution, Intersection of surfaces, Surface modelling, 16-point form, Coons patch, B-spline surfaces, Developing algorithms/computer codes for Design of Surfaces.

Design of Solids: Solid entities, Boolean operations, B-rep of Solid Modelling, CSG approach of solid modelling, Advanced modelling methods.

Applications of CAD Applications: Data exchange formats, Finite element analysis, mesh generation for finite element analysis, reverse engineering, modelling with point cloud data, working with .STL files, Additive Manufacturing.

Learning Resources:

Text Books:

1. Geometric Modeling, Michael E.Mortenson,TataMcGrawHill,2013.
2. Computer-AidedEngineering Design, A.SaxenaandB.Sahay,NamayaPublishers,NewDelhi,2005.

Reading:

1. Mathematical Elements for Computer Graphics, David F. Rogers, J. A. Adams, TMH, 2008.
2. Geometric Modeling, Michael E. Mortenson, Wiley, NY, 1997.
3. Product Design, Kevin N. Otto, Kristin L. Wood, Pearson Education, 2004.
4. CAD/CAM Theory and Practice, Ibrahim Zeid and Sivasubramanian, R., TataMcGraw Hill Publications, New Delhi, 2009.
5. Computer Aided Engineering Design, AnupamSaxena, BirendraSahay, Springer, 2005.

Online resources:

1. https://nptel.ac.in/courses/112/104/112104031/

DETAILED ELECTIVE COURSES SYLLABUS

(I – YEAR, I – SEMESTER)

ME5113	RENEWABLE SOURCES OF ENERGY	3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Identify the renewable energy sources, their utilization and storage
CO2	Understand the basic concepts of the solar radiation and analyze the solar thermal systems for their utilization
CO3	Understand the principle of working of solar cells and their modern manufacturing techniques
CO4	Analyze wind energy, biomass and Fuel cell systems and their applications
CO5	Design of solar thermal and energy storage systems for specific applications
CO6	Evaluate the energy conversion from ocean thermal energy, geothermal energy, biomass and magneto hydrodynamic power generation

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2	3	3
CO2	3	2	2	3	3	2
CO3	2	2	3	3	3	2
CO4	2	2	2	1	3	2
CO5	3	3	3	2	3	2
CO6	2	2	2	1	3	2

Syllabus:

Introduction: Overview of the course, Examination and Evaluation patterns. Classification of energy resources, Environmental Aspects of Energy – Global warming & Climate change – Role of Renewables, Energy-Environment-Economy, energy scenario in the world and India, Thermodynamics of Energy Sources – A brief review.

Energy storage: Necessity for energy storage. Classification of methods of energy storage. Thermal energy storage; sensible heat storage, latent heat storage., Mechanical energy storage: Pumped hydel storage, Compressed air storage and Flywheel storage, Reversible chemical reaction storage. Electromagnetic energy storage. Hydrogen energy storage. Chemical battery storage.

Basic sun-earth relationships: Definitions. Celestial sphere, altitude-azimuth, declination-hour angle and declination-right ascension coordinate systems for finding the position of the sun, celestial triangle and coordinates of the sun. Greenwich Mean Time, Indian Standard Time, Local Solar Time, sunrise and sunset times & day length.

Solar radiation: Nature of solar radiation, solar radiation spectrum, solar constant, extra-terrestrial radiation on a horizontal surface, attenuation of solar radiation, beam, diffuse and global radiation. Measurement of global, diffuse and beam radiation. Prediction of solar radiation; Angstrom model, Page model, Hottel's model, Liu and Jordan model etc. Insolation on an inclined surface, angle of incidence.

Solar thermal systems: Principle of working of solar water heating systems, solar cookers, solar desalination systems, solar ponds, solar chimney power plant, central power tower

power plants etc. Classification of solar concentrators, Basic definitions such as concentration ratio, angle of acceptance etc., Tracking of the sun; description of different tracking modes of solar collectors and the determination of angle of incidence of insolation in different tracking modes , Concept of Green building and associated design parameters.

Photovoltaic energy conversion: Introduction. Single crystal silicon solar cell, i-v characteristics, effect of insolation and temperature on the performance of silicon cells. Different types of solar cells. Modern technological methods of producing these cells. Indian and world photovoltaic energy scenario. Solar Cell, Module, and Array Construction, Maximizing the Solar PV Output and Load Matching.

Wind energy: Origin of winds, nature of winds, wind data measurement, Variation of Wind Speed with Height, Basics of fluid mechanics, Estimation of Wind Energy at a Site: Betz's law, Wind Turbine Aerodynamics, wind turbine types and their construction, wind-diesel hybrid system, environmental aspects, Wind Energy Storage, wind energy programme in India and the world.

Fuel cells: Introduction, applications, classification, different types of fuel cells such as phosphoric acid fuel cell, alkaline fuel cell, PEM fuel cell, MC fuel cell. Thermodynamic analysis of fuel cells, Development and performance fuel cells.

Biomass: Introduction, photosynthesis, biofuels, biomass resources, biomass conversion technologies, urban waste to energy conversion, biomass to ethanol conversion, biomass energy scenario in India, biogas production, constant pressure and constant volume biogas plants, operational parameters of the biogas plant, design of bio-digester, Energy Farming

Other forms of Energy: Ocean energy: Ocean thermal energy; open cycle & closed cycle OTEC plants, environmental impacts, challenges, present status of OTEC systems. Ocean tidal energy; single basin and double basin plants, their relative merits. Ocean wave energy; basics of ocean waves, different wave energy conversion devices, relative merits; **Geothermal energy:** Origin, applications, types of geothermal resources, relative merits; **Magneto hydrodynamic Power Generation:** applications; Origin and their types; Working principles.

Learning Resources:

Text Books:

1. Non conventional Energy Resources, B.H.Khan, Tata McGraw Hill, New Delhi, 2017, 3rd edition
2. Energy Technology: Non-Conventional, Renewable and Conventional, S.Rao and B.B.Parulekar, Khanna Publishers, 2010, 1st Edition.

Reference Books:

1. Solar Energy-Principles of Thermal Collection and Storage, S.P.Sukhatme and J.K.Nayak, TMH, 2010, 3rd edition (6 reprint).
2. Solar Energy Thermal Processes, J.A.Duffie and W.A.Beckman, John Wiley, 2013, 4th edition.

Online Resources:

1. Non-conventional Energy Resources by Prof. PrathapHaridoss (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/121/106/121106014/)

ME5114	ENERGY SYSTEMS AND MANAGEMENT	3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Understand the fundamentals of energy management
CO2	Apply the principles of thermal engineering and energy management to improve the performance of thermal systems.
CO3	Analyze the methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems.
CO4	Design viable energy projects.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	3	3	2
CO2	3		3	3	2	2
CO3	3	2	3	3	3	2
CO4	3	3	3	2	2	2

Syllabus:

Introduction: Review of the concepts of Thermodynamics, Fluid Mechanics and Heat Transfer, Need for energy storage, Grid balancing: Supply and demand concept for energy management. Heat transfer equipment- Heat exchangers, Steam plant

Energy storage Methods and systems: Thermal, Electrical and Mechanical energy storage methods and systems, Energy saving in IC engines and Gas turbines.

Direct Energy Conversion methods: Magneto-hydrodynamic (MHO) power generation, Thermionic power generation, Thermoelectric power generation, Fuel cells, Hydrogen energy system

Heat recovery systems: Incinerators, regenerators and boilers

Energy Conservation: Methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems

Energy Management: Principles of Energy Management, Energy demand estimation, Organising and Managing Energy Management Programs, Energy pricing

Energy Audit: Purpose, Methodology with respect to process Industries, Characteristic method employed in Certain Energy Intensive Industries, Economic Analysis: Scope, Characterization of an Investment Project and Case studies.

Learning Resources:

Text Books:

1. Energy Management audit & Conservation, De, B. K., Vrinda Publication, 2010, 2nd Edition.
2. Energy Management, Murphy, W. R., Elsevier, 2007, 1st Edition.

Reference Books:

1. Energy Management Hand book, Doty, S. and Truner, W. C., Fairmont Press, 2009,

7th edition.

Online Resources:

1. International Energy Agency Website, (Link: https://www.iea.org/)
2. Indian Renewable Energy Development Agency Limited Website, (Link: https://www.ireda.in)
3. Ministry of Power, GoI, Website, (Link: https://powermin.gov.in/)

ME5102	COMPUTATIONAL METHODS IN THERMAL ENGINEERING	3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Derive the governing equations and understand the behaviour of the equations.
CO2	Derive algebraic equations using finite volume methods for various fluid flow and heat transfer problems.
CO3	Solve systems of linear and non-linear equations using state of the art iterative algorithms.
CO4	Analyze the error and uncertainty in numerical models used for various algorithms.
CO5	Model the radiation heat transfer and turbulent flow problems using advanced techniques.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3		1
CO2	2	2	3	3		1
CO3	2	2	3	3		1
CO4	2	2	3	3		1
CO5	2	2	3	3		1

Syllabus:

Introduction: Revision of Fluid Mechanics and Heat transfer fundamentals.

Governing equations of fluid dynamics: The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

Finite volume method for diffusion problems: Derivation of equations for 1-D, 2-D and 3-D steady state diffusion, Solution of 1-D, 2-D and 3-D steady state heat conduction of slab.

Finite volume method for convection-diffusion problems: Conservativeness, Boundedness and Transportiveness, Central, Upwind, Hybrid and Power law schemes, QUICK and TVD schemes.

Pressure Velocity Coupling in steady flows: Staggered grid, SIMPLE algorithm, Assembly of a complete method, SIMPLER, SIMPLEC and PISO algorithms, Worked examples of the above algorithms.

Solution of discretized equations: Direct and Indirect or iterative methods, TDMA algorithm, Point-iterative methods (Jacobi method, Gauss-Seidel Method, Relaxation method), Multigrid methods

Finite volume method for 1-D unsteady flows: 1D unsteady heat conduction (Explicit, Crank-Nicolson and fully implicit schemes), Transient problems with QUICK, SIMPLE schemes, Implementation of boundary conditions: Inlet, Outlet, and Wall boundary conditions, Pressure boundary condition, Cyclic or Symmetric boundary condition.

Errors and uncertainty in CFD modelling: Numerical errors, Input uncertainty, Physical model uncertainty, Verification and validation, Guidelines for best practices in CFD, Reporting and documentation of CFD results.

CFD modelling of turbulent flows: Characteristics of turbulence, Effect of turbulent fluctuations on mean flow, Turbulent flow calculations, Turbulence modelling, Large Eddy Simulation, Direct Numerical Simulation.

Grid Generation: Unstructured grid generation, Domain nodalization, Domain triangulation, Advancing front methods, The Delaunay method, The respective algorithms with examples.

CFD for radiation heat transfer: Governing equations for radiation heat transfer, Popular radiation calculation techniques using CFD, The Monte-Carlo method, The discrete transfer method, Raytracing, The discrete ordinates method.

Learning Resources:

Text Books:

1. An introduction to computational fluid dynamics: the finite volume method, H.K. Versteeg, W. Malalasekera, Longman Group, England, 2007, 2nd Edition.
2. Computational Fluid Dynamics the Basics with Applications, Anderson. J.D(Jr), McGraw Hill Education, 2017.

Reference Books:

1. Computational Fluid Dynamics, Hoffman, K.A., and Chiang, S.T., Vol. I, II and III, Engineering Education System, 2000, 4th edition.
2. Computational Fluid Dynamics, Chung, T.J., Cambridge University Press, 2014, 2nd Edition.
3. Computational Fluid Mechanics and Heat Transfer, Anderson, D.A., Tannehill, J.C., and Pletcher, R.H., CRC Press, 2013, 3rd Edition.

Online Resources:

1. Computational Fluid Dynamics using Finite Volume Method by Dr.KameswararaoAnupindi (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106294/)
2. Foundations of Computational Fluid Dynamics by Prof. S. Vengadesan (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106186/)
3. Computational Fluid Dynamics by Prof. Suman Chakraborty (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105045/)

ME 5211	MICRO AND NANO MANUFACTURING	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Understand different techniques for the synthesis and characterization of nano-materials
CO2	Design and analyze methods and tools for micro and nano-manufacturing.
CO3	Select micro and nano-manufacturing methods and identify key variables to improve quality of MEMS.
CO4	Choose appropriate industrially viable process, equipment and tools for a specific product.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		2	1		1
CO2	2		3	2		
CO3	2		3	2	2	1
CO4	3		2	2	2	1

Syllabus:

Introduction: Importance of Nano-technology, Emergence of Nanotechnology, Bottom-up and Top-down approaches, challenges in Nanotechnology, Scaling Laws in Mechanics, fluids, thermodynamics, Electromagnetism, tribology and Examples. Trimmer force scaling vector.

Nano-materials Synthesis and Processing: Methods for creating Nanostructures; Processes for producing ultrafine powders- Mechanical grinding; Wet Chemical Synthesis of nano-materials- sol-gel process, Liquid solid reactions; Gas Phase synthesis of nano-materials- Furnace, Flame assisted ultrasonic spray pyrolysis; Gas Condensation Processing (GPC), Chemical Vapour Condensation(CVC)- Cold Plasma Methods, Laser ablation, Vapour – liquid –solid growth, particle precipitation aided CVD, summary of Gas Condensation Processing(GPC).

Structural Characterization: X-ray diffraction, Small angle X-ray Scattering, Optical Microscope and their description, Scanning Electron Microscopy (SEM), Scanning Probe Microscopy (SPM), TEM and EDAX analysis, Scanning Tunneling Microscopy (STM), Atomic force Microscopy (AFM).

Micro fabrication Techniques: Lithography, Thin Film Deposition and Doping, Etching and Substrate Removal, Substrate Bonding, MEMS Fabrication Techniques, Bulk Micromachining, Surface Micromachining, High- Aspect-Ratio Micromachining

Nanofabrication Techniques: E-Beam and Nano-Imprint Fabrication, Epitaxy and Strain Engineering, Scanned Probe Techniques, Self-Assembly and Template Manufacturing.

MEMS devices and applications: Pressure sensor, Inertial sensor, Optical MEMS and RF-MEMS, Micro-actuators for dual-stage servo systems.

Learning Resources:

Text Books:

1. MEMS and Microsystems: Design and Manufacture, Tai-Ran Hsu, McGraw- Hill, 2008
2. Fundamentals of Microfabrication: The Science of Miniaturization, Marc Madou, CRC Press, 2002, Second Edition.
3. Microfabrication and Nano manufacturing, Mark James Jackson, CRC Press, 2005.

Reference Books:

1. Introduction to Nanoscience and Nanotechnology, Gabor L. Hornyak, H.F Tibbals, Joydeep Dutta & John J Moore, CRC Press, 2009.
2. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, Ray F. Egerton, Springer, 2005.
3. Thermal Analysis of Materials, Robert F Speyer, Marcel Dekker Inc , New York, 1994.
4. Elements of X-Ray Diffraction, B.D. Cullity,, Prentice Hall , 2002, 3rd edition.

Online Videos

1. www.nptel.com

ME 5212	METROLOGY AND COMPUTER AIDED INSPECTION	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Explain the significance of calibration, traceability and uncertainty.
CO2	Identify measurement errors and suggest suitable techniques to minimize them.
CO3	Analyze the methods and devices for dimensional metrology.
CO4	Design limit gauges.
CO5	Assess surface roughness and form errors by computer aided inspection techniques.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2	1		2
CO2	2		2	2	2	
CO3	2		2	3	1	
CO4	3		2	2		
CO5	2		3	2	2	

Syllabus:

INTRODUCTION: Accuracy, precision, limits fits and tolerances, types of assemblies, linear and angular measurements, design of limit gauges for different applications.

SURFACE ROUGHNESS MEASUREMENT: Definitions – Types of Surface Texture: Surface Roughness Measurement Methods- Comparison, Contact and Non-Contact type roughness measuring devices, 3D Surface Roughness Measurement, Nano Level Surface Roughness Measurement – Instruments.

MEASUREMENT OF FORM ERRORS: Straightness, flatness, alignment errors-surface texture-various measuring instruments-run out and concentricity, Computational techniques in measurement of form errors.

INTERFEROMETRY: Introduction, Principles of light interference – Interferometers – Measurement and Calibration – Laser Interferometry.

COMPUTER AIDED LASER METROLOGY: Tool Makers Microscope, Coordinate Measuring Machines – Applications, Laser Micrometer, Laser Scanning gauge. Computer Aided Inspection techniques - In-process inspection, Machine Vision system-Applications, LASER micrometer, Point cloud data point, Reverse Engineering, Optical - LASER interferometers-applications.

IMAGE PROCESSING FOR METROLOGY: Overview, Computer imaging systems, Image Analysis, Pre-processing, Human vision system, Image model, Image enhancement, grey scale models, histogram models, Image Transforms – Examples.

Learning Resources:

Text Books:

1. A text-book of Metrology, M. Mahajan, DhanpatRai& Co, 2009.
2. Engineering Metrology, R. K. Jain, Khanna Publishers, 19/e, 2005.

Reference Books:

1. Engineering Metrology, K. J. Hume, Mc Donald & Co (Publishers), London, 1970.
2. Metrology for Engineers, J.F.W. Galyer and C.R.Shotbolt, ELBS Edition, 5/e, 1993.
3. Engineering Metrology, Thomas. G. G, Butterworth PUB.1974.

Online resources:

https://nptel.ac.in/

ME 5311	ENTERPRISE RESOURCE PLANNING	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Understand the concepts of ERP and managing risks.
CO2	Choose the technologies needed for ERP implementation.
CO3	Develop the implementation process.
CO4	Analyze the role of Consultants, Vendors and Employees.
CO5	Evaluate the role of PLM, SCM and CRM in ERP.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	2	2	1
CO2	2	1	2	2	3	2
CO3	2	2	2	2	2	1
CO4	2	1	2		1	1
CO5	2	1	2	2	2	1

Syllabus:

Introduction to ERP: Enterprise – an overview, brief history of ERP, common ERP myths, Role of CIO, Basic concepts of ERP, Risk factors of ERP implementation, Operation and Maintenance issues, Managing risk on ERP projects.

ERP and Related Technologies: BPR, Data Warehousing, Data Mining, OLAP, PLM, SCM, CRM, GIS, Intranets, Extranets, Middleware, Computer Security, Functional Modules of ERP Software, Integration of ERP, SCM and CRM applications.

ERP Implementation: Why ERP, ERP Implementation Life Cycle, ERP Package Selection, ERP Transition Strategies, ERP Implementation Process, ERP Project Teams.

ERP Operation and Maintenance: Role of Consultants, Vendors and Employees, Successes and Failure factors of ERP implementation, Maximizing the ERP system, ERP and e-Business, Future Directions and Trends.

Learning Resources:

Text Books:

1. Enterprise Resource Planning, Alexis Leon, Tata McGraw Hill, Second Edition, 2008.

2. ERP in Practice, Jagan Nathan Vaman, Tata McGraw Hill, 2007.

3. ERP: Tools, Techniques, and Applications for Integrating the Supply Chain, Carol A Ptak, CRC Press, 2003, 2nd Edition.

ME 5312	MANUFACTURING MANAGEMENT	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Design of production planning and control systems encompassing competitive priorities and strategies.
CO2	Evaluate and interpret Demand Forecast for production planning.
CO3	Design an optimal facility layout and select appropriate product design approach.
CO4	Apply ROP, MRP and JIT systems for inventory control in production systems by considering SCM issues.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	1	3	2
CO2	2		1	2	1	
CO3	3	2	2	2	2	1
CO4	2	1	2	3	3	1

Syllabus:

Competitive priorities and manufacturing strategy: Introduction, Historical perspective of manufacturing management, Competitive priorities and operational strategy, Functional area strategy and Capability, Case Study.

Demand Forecasting: Introduction, Quantitative Methods introduction, Time series and moving averages method, Exponential Smoothing method, Regression Analysis Method, Qualitative Methods.

Facility Design: Introduction and History, Product design and process selection, Capacity planning, Plant location and Plant layout.

Inventory control: From EOQ to ROP, Independent Demand Inventory control & Economic Order Quantity (EOQ), Dynamic lot sizing, Statistical inventory control models.

The MRP crusade: History, Need, Evolution, Dependent Demand & Material Requirement Planning (MRP), Structure of MRP system, MRP Calculations.

The JIT revolution: Just-in-Time System: origin & goals, Characteristics of JIT Systems, Continuous Improvement, The Kanban System, Strategic Implications of JIT System.

Production Planning and Control: Shop floor control, Production scheduling, Aggregate planning, Aggregate and workforce planning.

Supply Chain Management: Introduction to Supply Chain Management, Decision phases in a supply chain, Process views of a supply chain: push/pull and cycle views, Achieving Strategic fit, Expanding strategic scope.

Text Books:

1. Operations Management: Strategy and Analysis, Krajewski U and Ritzman LP, Pearson Education Pvt Ltd., Singapore, 2002.
2. Operations Management, Gaither N and Frazier G, Pearson, 12th Edition, 2001.

Reference Books:

1. Operations Management for Competitive Advantage, Chase RB, Aquilano NJ and Jacobs RF, McGraw-Hill Book Company, NY, 2001.

ME 5313	SOFT COMPUTING TECHNIQUES	3-0-0:3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Classify and differentiate problem solving methods and tools.
CO2	Apply A*, AO*, Branch and Bound search techniques for problem solving.
CO3	Formulate an optimization problem to solve using evolutionary computing methods.
CO4	Design and implement GA, PSO and ACO algorithms for optimization problems in Mechanical Engineering.
CO5	Apply soft computing techniques for design, control and optimization of Manufacturing systems.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			1			
CO2	2		2	3	1	
CO3	3		2	1	2	
CO4	3		3	3	2	
CO5	3	2	2	3	2	1

Syllabus:

Problem Solving Methods and Tools: Problem Space, Problem solving, State space, Algorithm's performance and complexity, Search Algorithms, Depth first search method, Breadth first search methods their comparison, A*, AO*, Branch and Bound search techniques, p type, Np complete and Np Hard problems.

Evolutionary Computing Methods: Principles of Evolutionary Processes and genetics, A history of Evolutionary computation and introduction to evolutionary algorithms, Genetic algorithms, Evolutionary strategy, Evolutionary programming, Genetic programming.

Genetic Algorithm and Genetic Programming: Basic concepts, working principle, procedures of GA, flow chart of GA, Genetic representations, (encoding) Initialization and selection, Genetic operators, Mutation, Generational Cycle, applications.

Swarm Optimization: Introduction to Swarm intelligence, Ant colony optimization (ACO), Particle swarm optimization (PSO), Artificial Bee colony algorithm (ABC), Other variants of swarm intelligence algorithms.

Advances in Soft Computing Tools: Fuzzy Logic, Theory and applications, Fuzzy Neural networks, Pattern Recognition, Differential Evolution, Data Mining Concepts, Applications of above algorithms in manufacturing engineering problems.

Deep Neural Networks: Neuron, Nerve structure and synapse, Artificial Neuron and its model, activation functions, Neural network architecture: single layer and multilayer feed forward networks, recurrent networks. Back propagation algorithm, factors affecting back propagation training, applications.

Application of Soft Computing to Mechanical Engineering/Production Engineering Problems: Application to Inventory control, Scheduling problems, Production, Distribution, Routing, Transportation, Assignment problems.

Learning Resources:

Text Books:

1. Soft Computing Integrating Evolutionary, Neural and Fuzzy Systems, Tettamanzi Andrea, Tomassini and Marco, Springer, 2001.
2. Artificial Intelligence, Elaine Rich, McGraw Hill, 2/e, 1990.
3. Multi-objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, John Wiley and Sons, 2001.
4. Optimization for Engineering Design: Algorithms and Examples, Kalyanmoy Deb, PHI, Ltd, 2012.

References:

1. https://in.mathworks.com/content/dam/mathworks/ebook/gated/machine-learning-ebook-all-chapters.pdf.

Online Resources:

1. https://www.iitk.ac.in/kangal/index.shtml

ME 5415	MATHEMATICAL METHODS IN ENGINEERING	3-0-0: 3

CourseOutcomes:

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

CO1	Formulate a design task as an optimization problem
CO2	Identifyconstrainedandunconstrainedoptimizationproblemsandsolveusing corresponding methods
CO3	Solve nonlinear optimization problems with evolutionary methods
CO4	Apply data driven methods to solve engineering problems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	1	2
CO2	2	2	3	3	2	2
CO3	3		3	3	3	2
CO4	3		3	3	3	2

Syllabus:

Mathematical Modeling: Modeling of systems related to mechanical engineering, assumptions, appropriate methods and fundamental of a computer implementation

Numerical Linear Equations: Introduction, Basic Ideas of Applied Linear Algebra, Systems of Linear Equations, Square, Non-Singular Systems, the Algebraic Eigenvalue Problem, Matrix Decompositions, Computer implementation of the methods for applications in engineering analysis.

Outline of Optimization Techniques: Introduction to Optimization, Multivariate Optimization, Constrained Optimization, Optimality Criteria, Computer implementation of the methods for applications in design optimization, manufacturing and thermal process optimization.

TopicsinNumericalAnalysis:Interpolation,Regression,NumericalIntegration,NumericalSolutionof ODE'sasIVP Boundary Value Problems. Application of numerical methods for research in mechanical engineering.

Overviews: PDE's and Variational Calculus: Separation of Variables in PDE's, Hyperbolic Equations, Parabolic and Elliptic Equations, Membrane Equation, and Calculus of Variations. Applications in mechanical engineering research.

Learning Resources:

1. Advanced Engineering Mathematics,E.Kreyszig,Wiley,2010.
2. Applied Mathematical Methods, B.Dasgupta,PearsonEducation,2006.
3. Scientific Computing, M.T.Heath,McGraw-HillEducation,2001.
4. Applied Numerical Methods with Matlab, StevenChapra,McGraw-HillEducation,2011.

ME 5613	MECHANICS OF METAL FORMING	3-0-0: 3

Pre-Requisites:Nil

Course Outcomes:

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

CO1	Understand the practical applications of metal forming.
CO2	Solve for strain rates, temperatures and metallurgical states in forming problems.
CO3	Develop process maps for metal forming processes using plasticity principles.
CO4	Estimate formability limits for sheets and bulk metals and workability of different ductile materials.
CO5	Apply FE principles to simulate metal forming processes.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		3	3	2	2
CO2	3		3	3	2	
CO3	3		3	3	2	2
CO4	3		3	3	2	
CO5	3		3	3	2	

Syllabus:

Introduction: Metal forming as a manufacturing process and its relation with other processes – Classification based on type of stresses - Examples.

Description of Material properties: Tensile test, effect of properties on forming. Sheet deformation processes: Uni-axial tension, general sheet forming processes, Yield criteria, Flow rule, Yield criterion and flow rule for Anisotropic material, work of plastic deformation, isotropic and anisotropic yield functions, Bauschinger effect modelling, effective stress and strain. Sheet deformation in plane stress: strain distributions, strain diagram, deformation modes, effective stress-strain laws, principal tensions.

Rolling Processes: Analysis of longitudinal strip or sheet rolling process (calculation of roll separating force, torque & power, angle of bite, maximum reduction in rolling), rolling defects.

Forging processes: Metal flow in forging, Analysis of plane strain compression, Analysis of compression of circular disc.

Extrusion Processes: Calculation of extrusion load, advances in extrusion, Defects in extrusion. Direct & indirect extrusion.

Wire Drawing Processes: Introduction, wire drawing load calculation.

Sheet forming: Mechanics: Flow Rules – Anisotropy - Formability of sheet, Formability tests, forming limit diagrams, strain path diagrams, Case studies.

Pressing and Sintering: Workability Studies – Densification

Recent advances: Hydroforming, tailor welded blanks, friction stir welding of sheets, incremental sheet forming.

Modelling and Simulation in Metal Forming: The Plane Strain Compression Test, FEM Model and Input Data to the Model - process simulation for deep drawing, Effective Strain and Strain-Rate, Distributions in Deformed Zones.

Case studies: Case studies on the manufacturing aspects of products using the lessons learnt.

Learning Resources:

Text Books:

5. Sheet metal forming processes Constitutive modelling and numerical simulation, D. Banabic, Springer-Verlag Berlin Heidelberg, 2010
6. Mechanics of sheet metal forming, Butterworth-Heinemann, Z. Marciniak, J. L. Duncan, S. J. Hu, Elsevier, 2002
7. Fundamentals of metal forming, R. H. Wagoner, J. L. Chenot, John Wiley and Sons, 1997
8. Metal forming Mechanics and Metallurgy, W. F. Hosford, R. M. Caddell, Printice Hall, 2007

Reference Books:

1. Modelling Techniques for Metal Forming Processes, G.K. Lal, P.M. Dixit and N.Venkat Reddy, Alpha Science, 2011
2. Theory of Plasticity, J. Chakrabarty, McGraw Hill, 1998.
3. Basic engineering plasticity, D. W. A. Rees, Elsevier, 2000
4. Theory of Engineering Plasticity, R. Narayanasamy, R Ponalagusamy, Ahuja Book Company, 2000.
5. Applied Metal Forming - Including FEM Analysis, Henry S. Valberg, Cambridge University Press, 2010.

ME5712	3D PRINTING	3-0-0: 3

Pre-Requisites: -NIL-

Course Outcomes:

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

CO1	Understand the working principles and process parameters of 3D printing processes
CO2	Explore different 3D printing processes and suggest suitable methods for building a particular component
CO3	Perform suitable post processing operation based on product repair requirement
CO4	Design and develop a working model using 3D printing Processes

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	2		2
CO2	2		2	3	2	2
CO3	2	2	3	3		2
CO4	3	3	3	2	3	2

Detailed Syllabus:

Introduction to Additive Manufacturing: Introduction to AM, AM evolution, Distinction Between AM & CNC machining, Steps in AM, Classification of AM processes, Advantages of AM and Types of materials for AM.

Vat Photopolymerization AM Processes: Stereolithography (SL), Materials, Process Modeling, SL resin curing process, SL scan patterns, Micro-stereolithography, Mask Projection Processes, Two-Photon vat photopolymerization, Process Benefits and Drawbacks, Applications of Vat Photopolymerization, case studies.

Material Jetting AM Processes: Evolution of Printing as an Additive Manufacturing Process, Materials, Process Benefits and Drawbacks, Applications of Material Jetting Processes.

Binder Jetting AM Processes: Materials, Process Benefits and Drawbacks, Research achievements in printing deposition, Technical challenges in printing, Applications of Binder Jetting Processes.

Extrusion-Based AM Processes: Fused Deposition Modelling (FDM), Principles, Materials, Process Modelling, Plotting and path control, Bio-Extrusion, Contour Crafting, Process Benefits and Drawbacks, Applications of Extrusion-Based Processes, case studies.

Sheet Lamination AM Processes: Bonding Mechanisms, Materials, Laminated Object Manufacturing (LOM), Ultrasonic Consolidation (UC), Gluing, Thermal bonding, LOM and UC applications, case studies.

Powder Bed Fusion AM Processes: Selective laser Sintering (SLS), Materials, Powder fusion mechanism and powder handling, Process Modelling, SLS Metal and ceramic part creation, Electron Beam melting (EBM), Process Benefits and Drawbacks, Applications of Powder Bed Fusion Processes, case studies.

Directed Energy Deposition AM Processes: Process Description, Material Delivery, Laser

Engineered Net Shaping (LENS), Direct Metal Deposition (DMD), Electron Beam Based Metal Deposition, Processing-structure-properties, relationships, Benefits and drawbacks, Applications of Directed Energy Deposition Processes. Friction stir additive manufacturing**:** process, parameters, advantages, limitations and applications, Additive friction stir deposition process: principle, parameters, applications, functionally graded additive manufacturing components, Case studies. **Wire Arc Additive Manufacturing:** Process, parameters, applications, advantages and disadvantages, case studies.

Materials science for AM - Multifunctional and graded materials in AM, Role of solidification rate, Evolution of non-equilibrium structure, microstructural studies, Structure property relationship, case studies.

Post Processing of AM Parts: Support Material Removal, Surface Texture Improvement, Accuracy Improvement, Aesthetic Improvement, Preparation for use as a Pattern, Property Enhancements using Non-thermal and Thermal Techniques, case studies.

Guidelines for Process Selection: Introduction, Selection Methods for a Part, Challenges of Selection, Example System for Preliminary Selection, Process Planning and Control.

Learning Resources:

Text Books:

1. Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Ian Gibson, David W Rosen, Brent Stucker, Springer, 2015, 2nd Edition.
2. 3D Printing and Additive Manufacturing: Principles & Applications, Chua Chee Kai, Leong Kah Fai, World Scientific, 2015, 4th Edition.

References Books:

1. Rapid Prototyping: Laser-based and Other Technologies, Patri K. Venuvinod and Weiyin Ma, Springer, 2004.
2. Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, D.T. Pham, S.S. Dimov, Springer 2001.
3. Rapid Prototyping: Principles and Applications in Manufacturing, Rafiq Noorani, John Wiley & Sons, 2006.
4. Additive Manufacturing, Second Edition, Amit Bandyopadhyay Susmita Bose, CRC Press

Taylor & Francis Group, 2020.

5. Additive Manufacturing: Principles, Technologies and Applications, C.P Paul, A.N Junoop, McGrawHill, 2021.

Online resources:

1. https://www.nist.gov/additive-manufacturing
2. https://www.metal-am.com/
3. http://additivemanufacturing.com/basics/
4. https://www.3dprintingindustry.com/
5. https://www.thingiverse.com/
6. https://reprap.org/wiki/RepRap

DETAILED LABORATORY COURSES SYLLABUS

(I – YEAR, I – SEMESTER)

ME 5305	MECHATRONICS AND AUTOMATION LABORATORY	0-1-2: 2

Pre-requisites: NIL

Course Outcomes:

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

CO1	Measure load, displacement and temperature using analogue and digital sensors.
CO2	Develop PLC programs for control of traffic lights, water level, lift and conveyor belt.
CO3	Develop P89V51RD2, Arduino & Raspberry Pi microcontroller program to guide a robot in a given arena.
CO4	Simulate and analyze PD, PI and PID controllers for a given physical system using MATLAB.
CO5	Develop pneumatic and hydraulic circuits using Automation studio

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1		2	3	2		2
CO2		2	3	3	3	2
CO3		2	3	3	3	2
CO4		2	3	3	3	2
CO5		2	3	3	3	2

Syllabus:

LIST OF EXPERIMENTS

1. **DYNA 1750 Transducers Kit :**
   a. Characteristics of LVDT
   b. Principle & Characteristics of Strain Gauge
   c. Characteristics of Summing Amplifier
   d. Characteristics of Reflective Opto Transducer
2. **Mobile Robot with P89V51RD2 microcontroller, Arduino, Raspberry Pi Programming**
   a. Program for Operating Buzzer Beep
   b. Program for Operating Motion control
   c. Program for Operating Direction control
   d. Program for Operating White line follower for the given arena
3. **PLC PROGRAMMING**
   a. Ladder programming on Logic gates, Timers & counters
   b. Ladder Programming for digital & Analogy sensors
   c. Ladder programming for Traffic Light control, Water level control and Lift control Modules
4. **AUTOMATION STUDIO software**
   a. Introduction to Automation studio & its control
   b. Draw & Simulate the Hydraulic circuit for series & parallel cylinders connection
   c. Draw & Simulate Meter-in, Meter-out and hydraulic press and clamping.
5. **MATLAB Programming**

a. Sample programmes on Mat lab
b. Simulation and analysis of PID controller using SIMULINK

Learning Resources:

Text Books

1. Mechatronics Lab Manual
2. Mechatronics Systems Design, Cengage Learning, Devadas Shetty, USA, 2012.
3. Fluid Power, Jagadesesha T., T Gowda., Wiley, USA,2013

ME 5206	CAE LABORATORY	0-1-2: 2

Pre-Requisites: NIL

Course Outcomes:

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

CO1	Draw complex geometries of parts in sketch mode.
CO2	Develop MATLAB codes for analytical and synthetic curves.
CO3	Create complex engineering assemblies using appropriate assembly constraints.
CO4	Practice on CAD data exchange formats used in design and analysis of Engineering components.
CO5	Analyse 2D/3D components using a FEA software.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2				2
CO2	3	2	2	3	2	2
CO3	3	2	2			2
CO4	3	3	2	2	2	2
CO5	3	3	2	3	2	2

Syllabus

LIST OF EXPERIMENTS:

1. Introduction to Solid Modelling Packages
2. Working with sketch mode of Solid modelling Package
3. Working with creating features (Extrude & Revolve)
4. Develop MATLAB Code for various analytical curves
5. Develop MATLAB Code for various synthetic curves
6. Working with various editing tools in Solid Modelling
7. Working with advanced modelling tools (Sweep, Blend & Swept Blend)
8. Assembly modelling using appropriate assembly constrains
9. Working with CAD Data Exchange formats: IGES, ACIS, DXF STL, AMF, STEP
10. Analysis of simple 2D/3D component using a FEA software

Learning Resources:

Text Books:

1. Applied Numerical Methods with MATLAB for Engineers & Scientists, Steven Chapra, McGraw-Hill, 2018, 4th Edition.
2. AutoCAD 2017 for Engineers & Designers, Sham Tickoo, Dreamtech Press, 23rd Edition,2016.
3. Autodesk Fusion 360 Black Book, Verma G., CAD CAM CAE Works, 2021, 2nd Edition.

Reference Books:

1. Principles of CAD/CAM/CAE, Kunwoo Lee, Pearson, 1999.
2. Engineering Computation with MATLAB, David Smith, Pearson, 2013, 3rd Edition.

Online Resources:

1. Self-Paced Tutorials https://help.autodesk.com/view/fusion360/ENU/courses/
2. Product Documentation: https://help.autodesk.com/view/fusion360/ENU/?guid=GUID-1C665B4D-7BF7-4FDF-98B0-AA7EE12B5AC2
3. https://sites.ualberta.ca/~wmoussa/AnsysTutorial/
4. https://www.ansys.com/en-in/academic/learning-resources
5. http://engineering.nyu.edu/mechatronics/vkapila/matlabtutor.html

ME 5348	SEMINAR I	0-0-3: 1

Pre-requisites: NIL

Course Outcomes:

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

CO1	Identify and compare technical and practical issues related to the area of course specialization
CO2	Outline annotated bibliography of research demonstrating scholarly skills.
CO3	Prepare a well-organized report employing elements of technical writing and critical thinking
CO4	Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2			3
CO2	3	2	2			3
CO3	3	3	2			3
CO4	3	3	2			3

Syllabus:

1. Identify the topic from scientific online resources
2. Conduct literature survey from the identified topic
3. Understand the identified topic and explore the contents critically

Task	Description	Weightage
I	Clarity on the topic	10
II	Literature survey	30
III	Content	30
IV	Presentation	20
V	Response to Questions	10
TOTAL		100

Task-CO mapping:

Task/CO	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X
V				X

Learning Resources

References:

1. https://www.sciencedirect.com/
2. https://scholar.google.com/

CORE COURSES DETAILED SYLLABUS

(I – YEAR, II – SEMESTER)

ME 5351	SYSTEM APPROACH TO CIM	3-0-0: 3

Pre-requisites:NIL

Course Outcomes:

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

CO1	Understand the effect of manufacturing automation strategies and derive production metrics
CO2	Analyze automated flowlines and assembly systems, and balance the line.
CO3	Design automatedmaterialhandlingandstoragesystemsforatypicalproductionsystem.
CO4	Design a manufacturing cell and cellular manufacturing system.
CO5	Design and develop Computer Integrated Manufacturing Systems.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		2			
CO2	2		2	2	3	
CO3	2		2	2	3	
CO4	1		2	2	3	
CO5	2		2	2	3	

Syllabus:

Manufacturing Automation: Automated Manufacturing Systems, Computerized Manufacturing Support Systems, Reasons and Strategies, Applications of manufacturing automation.

Automated Flow lines: System Configurations, Work-part Transfer Mechanisms, Storage Buffers, Automated flow lines with and without storage buffer Control, Transfer mechanism, Analysis of Production Transfer Line.

Manual Assembly Lines: Fundamentals of manual assembly lines**,** Assembly Workstations, Work Transport Systems, Line Pacing, Coping With Product Variety, Analysis of Single Model Assembly Lines-Repositioning Losses, The Line Balancing Problem, Line Balancing Algorithms.

Automated Assembly Systems: Need for automated assembly system, Design for automated assembly, System Configurations and Applications of Parts Delivery at Workstations, Quantitative Analysis of Assembly Systems.

Automatic Material Handling and Storage systems: Design Considerations in Material Handling, Material Transport Equipment- Automated Guided Vehicles. Automated Storage/Retrieval Systems, Carousel Storage Systems, Engineering Analysis of AS/RS and Carousel Systems.

Automated Inspection systems: Overview of Automated Identification Methods, Bar Code Technology, Radio Frequency Identification, Other AIDC Technologies.

Cellular Manufacturing Systems: Part Families, Features and Optiz of Parts Classification and Coding Systems, Production Flow Analysis, Composite Part Concept, Machine Cell Design, Applications Of Group Technology, Quantitative analysis of Cellular Manufacturing, Grouping of parts and Machines by Rank Order Clustering, Arranging Machines in a GT Cell.

Computer Aided Process Planning: Retrieval CAPP Systems, Generative CAPP Systems, Feature Identification-Algorithms.

Flexible Manufacturing Systems: Flexibility, Types Of FMS, FMS Components, Computer Control System, Human Recourses, FMS Applications and Benefits

Computer Integrated Manufacturing: The Scope of CAD/CAM and CIM, Computerized elements, Planning, Scheduling, Analysis and Components of a CIM, System, Database for CIM.

Learning Resources:

Text Books:

1. Automation, production Systems and Computer Integrated Manufacturing, Mikell P Groover, Prentice Hall Inc., New Delhi, 2012, 3rd Edition.
2. System Approach to Computer Integrated Manufacturing, Nanua Singh, Wiley & Sons Inc., 1996.
3. Intelligent Manufacturing System, Prentice Hall Inc., Andrew Kusiak, New Jersey, 1992

Reference Books:

1. Principles of computer integrated manufacturing, S. Kant Vajpayee, Prentice- Hall International, 1995

ME 5352	FACTORY AUTOMATION	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Understand automation and its influence on Manufacturing.
CO2	Apply fixed automation principles to develop fluidic devices.
CO3	Analyse and develop computerized controls for programmable automation.
CO4	Design flexible automation devices and integrate them to develop advanced Manufacturing.
CO5	Adapting IT security methods to factory automation

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			2		2	2
CO2	2		2	2		
CO3	2		2	3	2	
CO4	2		3	2	2	1
CO5	2		2	3	3	1

Syllabus:

Factory Automation: Introduction, Elements, Types and Applications of Automation, Low Cost Automation, Hierarchical levels in Factory Automation.

Fixed/Hard Automation: Overview of pneumatic elements/hydraulic elements, Industrial hydraulic systems, design of hydraulic, pneumatic, Hydro pneumatics, pneumatic logic controls. Electric control of fluid power, low cost automation. Introduction of Fluidics, Boolean Algebra, Law of Boolean Algebra, Truth Table, Logic gates, Origin and development of Fluidics, Fluidic devices, Fluidic logic devices, Fluidic sensors, Fluidics amplifier, and case studies.

Programmable Automation: Control Technologies in automation: Industrial control systems, process industries Vs Discrete manufacturing industries, Continuous Vs discrete control, computer process control and its form. Computer based Industrial control, Analog and Digital I/O modules, Supervisory Control and Data Acquisition Systems (SCADA) and Remote Terminal Unit (RTU). Electrical and electronics controls: Sensors and Transducers, Programming Logic Controllers (PLC), Integration of mechanical system with computer and electronics systems and case studies, Internet of things (IoT) for plant automation.

Flexible Automation: Flexible manufacturing cells and systems, Material handling System: Conventional material handling systems, Automated material handling systems. Automated Storage and Retrieval System, System integration, protocols and advanced communication in manufacturing system with case studies.

Future automation in Factory: Applications of AI in hierarchical levels of Factory Automation. Paradigms- Considerations in adapting IT security methods to factory automation, Threats, IT and industrial automation.

Learning Resources:

Text Books:

1. Automation Production Systems, and Computer Integrated Manufacturing, Mikell P. Groover, PHIPvt Ltd, New Delhi, 2013
2. Industrial Automation and Robotics, KhushdeepGoyal and Deepak Bhandari, S.K.Kataria sons, New Delhi , 2008
3. 3. Computer-Based Industrial Control,Krishna Kant, PHI Pvt Ltd, New Delhi, 2010.
4. Industrial control handbook,Parr, Newmen, Industrial Press in New York, N.Y.
5. Industrial Automation and Control System Security Principles: Protecting the Critical Infrastructure, Ronald L. Krutz, International Society of Automation, 2017, 2nd Edition.
6. Industrial Network Security, - David J. Teumim, International Society of Automation, 2010, Second Edition.

Reference Books:

1. Artificial Intelligence: A Modern Approach, Stuart Russell and Peter Norvig, Prentice Hall, 2003. 2nd Edition.

ELECTIVE COURSES DETAILED SYLLABUS

(I – YEAR, II– SEMESTER)

ME5170	ESSENTIALS OF ENTREPRENEURSHIP	3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Understand entrepreneurship and entrepreneurial process and its significance in economic development
CO2	Develop an idea of the support structure and promotional agencies assisting ethical entrepreneurship
CO3	Identify entrepreneurial opportunities, support and resource requirements to launch a new venture within legal and formal framework
CO4	Develop a framework for technical, economic and financial feasibility to prepare a written business plan
CO5	Understand the stages of establishment, growth, barriers, and causes of sickness in industry to initiate appropriate strategies for operation, stabilization and growth

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	1			2
CO2	2	3	3			3
CO3	1	2	1		2	2
CO4	2	3	3		2	3
CO5	3	2	1		2	3

Syllabus:

Entrepreneur and Entrepreneurship: Introduction; Entrepreneur and Entrepreneurship; Role of entrepreneurship in economic development; Entrepreneurial competencies and motivation; EDP models, Institutional Interface for Small Scale Industry/Enterprises.

Business Idea generation: Opportunity Scanning and Identification; Creativity and product development process; The technology challenge – Innovation in a knowledge-based economy, sources of innovation pulses – Internal and external; Drucker's 7 sources of innovation impulses, General innovation tools, role of innovation during venture growth; Market survey and assessment; choice of technology and selection of site.

Planning a Start-up Enterprise: Forms of business organization/ ownership; Financing new enterprises – sources of capital for early-stage technology companies; Techno Economic Feasibility Assessment; Preparation of Business Plan for grants, loans and venture capital.

Operational Issues for new enterprises: Financial management issues; Operational/ project management issues in SSE; Marketing management issues in SSE; Relevant business and industrial Laws.

Performance appraisal and growth strategies: Strategies to anticipate and avoid pitfalls associated with launching and leading a technology venture; Management performance

assessment and control; Causes of Sickness in SSI, Strategies for Stabilization and Growth.

Learning Resources:

Text Books:

1. Technology Ventures: From Ideas to Enterprise, Byers, Dorf, and Nelson, McGraw Hill. ISBN-13: 978-0073380186., 2010
2. Entrepreneurship: Successfully Launching New Ventures, Bruce R Barringer and R Duane Ireland, Pearson Edu., 2013 3rd ed.
3. Entrepreneurial Development, S.S. Khanka, S Chand & Company Ltd., 2012, 4th ed.
4. Entrepreneurship: A South-Asian Perspective, D.F. Kuratko and T.V. Rao, Cengage Learning, 2013.

Reference Books:

1. A Handbook for New Entrepreneurs, Entrepreneurship Development Institute of India, Ahmedabad, 1988.
2. The practice of entrepreneurship, G.G. Meredith, R.E. Nelson & P.A. Neck, ILO, 1982
3. Management of Small-Scale Enterprises, Dr. Vasant Desai, Himalaya Publishing House, 2004.

ME5173	ENERGY CONSERVATION AND WASTE HEAT RECOVERY	3-0-0: 3

Prerequisites: NIL

Course Outcomes:

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

CO1	Identify and assess the energy conservation opportunities in different thermal systems
CO2	Outline the methods of energy storage and identify the appropriate methods of energy storage for specific applications
CO3	Understand the energy conversion techniques
CO4	Evaluate the performance of heat recovery system for industrial applications

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	3	1	3	3
CO2	1	1	3	1	3	3
CO3	1	1	3	1	3	3
CO4	2	1	3	3	3	3

Syllabus:

INTRODUCTION: Overview of the course; Examination and Evaluation patterns; Basic concepts of energy; Energy and Environment: Global warming, acid rains.

ENERGY STORAGE: Need for energy storage, thermal, electrical, magnetic and chemical energy storage systems.

FUEL COMBUSTION AND GASIFICATION: Fuel Composition and Heating Value; Combustion stoichiometry and calculation; Gaseous product combustion; Coal gasification; Gasification process and gasifiers.

ENERGY CONSERVATION: Introduction; Principles of thermodynamics: Rankine and Brayton cycles; enhancement of efficiency by reheat, regenerative, intercooling; topping, bottoming and combined cycles; concept of tri generation; Boilers :Types, Performance evaluation of boilers, Boiler Water Treatment and blow down, Introduction to FBC Boilers, Mechanism and Operational Features of FBC, Retrofitting FBC system to conventional boilers.

WASTE HEAT RECOVERY: Classification, Advantages and applications, Selection criteria for waste heat recovery technologies, waste heat recovery devices: recuperators, regenerators, economizers, plate heat exchangers, thermic fluid heaters, Waste heat boilers-design aspects; fluidized bed heat exchangers, heat pipe exchangers, heat pumps; Saving potential.

Learning Resources:

Text Books:

1. Energy Storage, J Jensen, Elsevier, 2013

Reference Books:

1. Lee SS EDS, Seagate Subrata, Waste Heat Utilization and Management, Hemisphere, Washington, 1983.
2. Advance Energy Systems, Nikolai V. Khartchenko, Taylor and Francis Publishing, 2013, 2nd Edition.
3. Powerplant Technology, M.M.El-Wakil, Tata McGraw Hill, 20103, Indian Edition

Online Resources:

1. Bureau of Energy Standards Official Website, Link: https://www.beeindia.gov.in

ME 5262	PRODUCT DESIGN FOR MANUFACTURING AND ASSEMBLY	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Understand the quality aspects of design for manufacture and assembly.
CO2	Apply Boothroyd method of DFM for product design and assembly.
CO3	Apply the concept of DFM for casting, welding, forming and assembly.
CO4	Identify the design factors and processes as per customer specifications.
CO5	Apply the DFM method for a given product.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	1	1		1
CO2	2	1		2		
CO3	2	3		2		1
CO4	2	1	1	1		2
CO5	2	3	1	2	2	1

Syllabus:

Introduction to DFM, DFMA: How Does DFMA Work, Reasons for Not Implementing DFMA, What Are the Advantages of Applying DFMA During Product Design, Typical DFMA Case Studies, Overall Impact of DFMA on Industry.

Design for Manual Assembly: General Design Guidelines for Manual Assembly, Development of the Systematic DFA Methodology, Assembly Efficiency, Effect of Part Symmetry, Thickness, and Weight on Handling Time, Effects of Combinations of Factors, Application of the DFA Methodology.

High speed Automatic Assembly & Robot Assembly: Design of Parts for High-Speed Feeding and Orienting, Additional Feeding Difficulties, High-Speed Automatic Insertion, General Rules for Product Design for Automation, Design of Parts for Feeding and Orienting, Product Design for Robot Assembly.

Design for Machining and Injection Molding: Machining Using Single-Point & Multi point cutting tools, Choice of Work Material, Shape of Work Material, Machining Basic Component Shapes, Cost Estimating for Machined Components, Injection Molding Materials, The Molding Cycle, Injection Molding Systems, Molding Machine Size, Molding Cycle Time, Estimation of the Optimum Number of Cavities, Design Guidelines.

Design for Sheet Metal working & Die Casting: Dedicated Dies and Press-working, Press Selection, Turret Press working, Press Brake Operations, Design Rules, The Die Casting Cycle, Auxiliary Equipment for Automation, Determination of the Optimum Number of Cavities, Determination of Appropriate Machine Size, Die Casting Cycle Time Estimation, Die Cost Estimation, Design Principles.

Design for Assembly Automation: Fundamentals of automated assembly systems, System configurations, parts delivery system at workstations, various escapement and placement devices used in automated *a*ssembly systems, Quantitative analysis of Assembly systems, Multi station assembly systems, single station assembly lines.

Learning Resources:

Text Books:

1. Assembly Automation and Product Design, Geoffrey Boothroyd, Marcel Dekker Inc., NY, 3rd Edition,2010.

Reference books:

1. Hand Book of Product Design, Geoffrey Boothroyd, Marcel Dekker Inc., NY, 1992.

Online resources:

https://nptel.ac.in/noc/courses/noc21/SEM1/noc21-me66/
https://www.rapiddirect.com/blog/design-for-assembly/

ME 5264	GEOMETRIC DIMENSIONING AND TOLERANCING	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Interpret GDT symbols on a print.
CO2	Identify minimum and maximum material conditions
CO3	Measure and verify position tolerances with applied material conditions
CO4	Apply basic rectangular datum reference frames

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3		
CO2	3		3	3		
CO3	3		3	3		
CO4	3	3	3	3		

Syllabus:

Introduction:

Scope, Definitions, Fundamental Rules, Units of Measure, Types of Dimensioning, Application of Dimensions, Dimensioning Features, Location of Features

Principles of Tolerancing:

Direct Tolerancing Methods, Tolerance Expression, Interpretation of Limits, Single Limits, Tolerance Accumulation, Limits of Size, Applicability of Modifiers on Geometric Tolerance Values and Datum Feature References, Screw Methods, Gears and Splines, Boundary Conditions, Angular Surfaces, Conical Tapers, Flat Tapers, Radius, Tangent Plane, Statistical Tolerancing.

Symbology:

Use of Notes to Supplement Symbols, Symbol Construction, Feature Control Frame Symbols, Feature Control Placement, Definition of Tolerance Zone, Tabulated Tolerances

Datum Reference Frames:

Degrees of Freedom, Degrees of Freedom Constrained by Primary Datum Features, Regardless of Material Boundary, Constraining Degrees of Freedom of a Part, Datum Feature Simulator, Theoretical and Physical Application of Datum Feature Simulators, Datum Reference Frame, Datum Features and Controls, Specifying Datum Features in an Order of Precedence, Establishing Datums, Multiple Datum Features, Mathematically Defined Surface, Multiple Datum reference Frames, Functional Datum Features, Rotational Constraint about a Datum Axis or Point, Application of MMB, LMB and RMB to Irregular Features of Size, Datum Feature Selection Practical Applications, Simultaneous Requirements, Restrained Condition, Datum Reference Frame Identification, Customized Datum Reference Frame Construction, Application of a Customized Datum Reference Frame, Datum Targets

Form Tolerances:

Form Control, Specifying Form Tolerances, Application of Free-State Symbol

Orientation Tolerances:
Orientation Control, Orientation Symbols, Specifying Orientation Tolerances, Tangent Plane, Alternative Practice

Location Tolerances:
Positional Tolerancing, Positional Tolerancing Fundamentals – I and II, Pattern Location, Coaxial Feature Controls, Tolerancing for Symmetrical Relationships

Profile Tolerances:
Profile, Tolerance Zone Boundaries, Profile Applications, Material Condition and Boundary Condition Modifiers as Composite Profile, Multiple Single-Segment Profile Tolerancing, Combined Controls

Runout Tolerances:
Runout, Runout Tolerance, types of Runout Tolerances, Applications, Specification.

Learning Resources:

Text Books:

1. Geometric Dimensioning and Tolerancing by P.S. Gill, (Publ.) S. K. Kataria& Sons, 2009
2. Geometric Dimensioning and Tolerancing: Applications and Techniques for Use in Design: Manufacturing, and Inspection, by James D. Meadows, CRC Press, 1995

Reference Books:

1. Simplified GD & T: Based on ASME-Y 14.5-2009 by Ashok Kumar 2nd Edition, Azuko*Publishing* 2009

Online resources:
https://www.gd-t.com/resources

http://www.etinews.com/free_gdt_resources.html

https://formlabs.com/blog/gdt-geometric-dimensioning-and-tolerancing/

ME 5265	MECHATRONICS AND ROBOTICS	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1.	Model, analyze and control engineering systems.
CO2.	Select appropriate sensors, transducers and actuators to monitor and control the behavior of a process or product.
CO3.	Develop PLC programs for a given task.
CO4.	Evaluate the performance of mechatronic systems.
CO5.	Understand the evolution, classification, structures and drives for robots.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2	3		
CO2	3	2	2	3	2	
CO3	2		2	3		
CO4	1	1	2	3		2
CO5	1		2	3		

Syllabus:

Introduction: Overview of the course, Examination and Evaluation patterns, History of Mechatronics, Scope and Significance of Mechatronics systems, elements of mechatronic systems, needs and benefits of mechatronics in manufacturing.

Sensors: Classification of sensors basic working principles, Displacement Sensor - Linear and rotary potentiometers, LVDT and RVDT, incremental and absolute encoders. Strain gauges. Force/Torque – Load cells. Temperature – Thermocouple, Bimetallic Strips, Thermistor, RTD Accelerometers, Velocity sensors – Tachometers, Proximity and Range sensors – Eddy current sensor, ultrasonic sensor, laser interferometer transducer, Hall Effect sensor, inductive proximity switch. Light sensors – Photodiodes, phototransistors, Flow sensors – Ultrasonic sensor, laser Doppler anemometer tactile sensors – PVDF tactile sensor, micro-switch and reed switch Piezoelectric sensors, vision sensor.

Actuators: Electrical Actuators: Solenoids, relays, diodes, thyristors, triacs, BJT, FET, DC motor, Servo motor, BLDC Motor, AC Motor, stepper motors. Hydraulic & Pneumatic devices – Power supplies, valves, cylinder sequencing. Design of Hydraulic & Pneumatic circuits. Piezoelectric actuators, Shape memory alloys.

Basic System Models & Analysis: Modelling of one and two degrees of freedom Mechanical, Electrical, Fluid and thermal systems, Block diagram representations for these systems. Dynamic Responses of System: Transfer function, Modelling Dynamic systems, first order systems, second order systems.

Digital Electronics: Number systems, BCD codes and arithmetic, Gray codes, self-complimenting codes, Error detection and correction principles. Boolean functions using Karnaugh map, Design of combinational circuits, Design of arithmetic circuits. Design of Code converters, Encoders and decoders.

Signal Conditioning: Operational amplifiers, inverting amplifier, differential amplifier, Protection, comparator, filters, Multiplexer, Pulse width Modulation Counters, decoders. Data acquisition – Quantizing theory, Analog to digital conversion, digital to analog conversion.

Controllers: Classification of control systems, Feedback, closed loop and open loop systems, Continuous and discrete processes, control modes, Two step Proportional, Derivative, Integral, PID controllers.

PLC Programming: PLC Principles of operation PLC sizes PLC hardware components I/O section Analog I/O section Analog I/O modules, digital I/O modules CPU Processor memory module Programming. Ladder Programming, ladder diagrams, timers, internal relays and counters, data handling, analogue input and output. Application on real time industrial automation systems.

Case studies of Mechatronics systems: Pick and place robot, Bar code, Engine Management system, Washing machine etc.

Robotics: Introduction to Robotics, Robot anatomy physical configurations, Manipulator, Kinematics, Technical features. Programming of Mobile robot, robot programming language, end effecters.

Learning Resources:

Text Books:

1. Mechatronics, W. Bolton, 5 th edition, Addison Wesley Longman Ltd, 2010
2. Mechatronics System Design, DevdasShetty& Richard Kolk, 3rd edition. PWS Publishing, 2009.
3. Introduction to Mechatronics and Measurement systems, Alciatore David G &Histand Michael B, 4th edition, Tata McGraw Hill, 2006.

Reference Resources:

1. Introduction to Robotics: Analysis, Systems, Applications, Saeed B Niku, 2nd edition, Pearson Education India, PHI, 2003.

Online Sources

1. http://video_demos.colostate.edu/mechatronics

http:// mechatronics.me.wisc.edu

ME5266	PRECISION MANUFACTURING	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

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

CO1	Understand the concept of accuracy and precision
CO2	Apply fits and tolerances for parts and assemblies as per ISO standards.
CO3	Evaluate the machine tool and part accuracies.
CO4	Estimate the surface quality of machined components

Course Articulation Matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		3	3	2	
CO2	3		3	3	2	
CO3	3		3	3	2	
CO4	2		2	2	2	

Syllabus:

Accuracy and Precision: Introduction - Accuracy and precision – Need – application of precision machining- alignment testing of machine tools, accuracy of numerical control system, specification of accuracy of parts and assemblies.

Tolerance and fits: Tolerance and fits, hole and shaft basis system, types of fits- Types of assemblies-probability of clearance and interference fits in transitional fits.

Concept of part and machine tool accuracy: Specification of accuracyof parts and assemblies, accuracy of machine tools, alignment testing of machine tools.

Errors during machining: Errors due to compliance of machine-fixture-tool-work piece (MFTW) System, theory of location, location errors, errors due to geometric inaccuracy of machine tool, errors due to tool wear, errors due to thermal effects, errors due to clamping. Statistical methods of accuracy analysis.

Surface roughness: Definition and measurement, surface roughness indicators (CLA, RMS, etc,.) and their comparison, influence of machining conditions, methods of obtaining high quality surfaces, Lapping, Honing, Super finishing and Burnishing processes.

Learning resources:

Text Books:

1. Precision Engineering in Manufacturing, R.L.Murty, New Age International Publishers, 1996.
2. Fundamentals of Process Engineering, V.Kovan, Foreign Languages Publishing House, Moscow, 1975

Reference books:

1. Process Engineering for Manufacture, Eary and Johnson,Prentice Hall, 1962.
2. Dimensional control in Precision Manufacturing, J.L.Gadjala, McGraw Hill Publishers, 2012.

Online resources:
https://www.nptel.ac.in/
https://precisionmfg.com/

https://cmti.res.in/precision-manufacturing-and-process-engineering/

ME 5361	SUPPLY CHAIN MANAGEMENT	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Understand the decision phases and apply competitive and supply chain strategies.
CO2	Understand drivers of supply chain performance.
CO3	Analyze factors influencing network design.
CO4	Analyze the role of forecasting in a supply chain
CO5	Understand the role of aggregate planning, inventory, IT and coordination in a supp chain.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
5170CO1	2		2		2	1
CO2	2	1	2		2	1
CO3	3	1	2	2	2	1
CO4	2		2	2	2	1
CO5	2	1	2	3	2	1

Syllabus:

Strategic Framework: Introduction to Supply Chain Management, Decision phases in a supply chain, Process views of a supply chain: push/pull and cycle views, Achieving Strategic fit, Expanding strategic scope.

Supply Chain Drivers and Metrics: Drivers of supply chain performance, Framework for structuring Drivers, Obstacles to achieving strategic fit.

Designing Supply Chain Network: Factors influencing Distribution Network Design, Design options for a Distribution network, E-Business and Distribution network, Framework for Network Design Decisions, Models for Facility Location and Capacity Allocation.

Forecasting in SC: Role of forecasting in a supply chain, Components of a forecast and forecasting methods, Risk management in forecasting.

Aggregate Planning and Inventories in SC: Aggregate planning problem in SC, Aggregate Planning Strategies, Planning Supply and Demand in a SC, Managing uncertainty in a SC: Safety Inventory.

Coordination in SC: Modes of Transportation and their performance characteristics, Supply Chain IT framework, Coordination in a SC and Bullwhip Effect.

Learning Resources:

Text Books:

1. Supply Chain Management - Strategy, Planning and Operation, Sunil Chopra and Peter Meindl, Pearson Education Asia, 2010, 4th Edition.

2. Designing and Managing the Supply Chain - Concepts Strategies and Case Studies, David Simchi-Levi, PhilpKamintry and Edith Simchy Levy, Tata-McGraw Hill, 2000, 2nd Edition.
3. Managing Supply Chains A Logistics Approach', John J Coyle, Cengage Learning, 2013, 9th Edition.
4. Modeling the Supply Chain', Jeremy F Shapiro, Cengage Learning, 2007, 2nd Edition.

Online Resources:

1. https://scm.mit.edu/

ME 5362	MODELLING AND SIMULATION OF MANUFACTURING SYSTEMS	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Classify analytical and simulation models used in manufacturing system environment
CO2	Apply probability and simulation languages
CO3	Design and evaluate a given manufacturing system using simulation
CO4	Generate random numbers and variants to execute a simulation model
CO5	Evaluate queuing networks and Markov chains in the context of manufacturing

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2	3	2	1
CO2	2	1	2	2	2	1
CO3	2	1	2	2	2	1
CO4			2	2		
CO5	2	1	2	2	2	1

Syllabus:

Introduction to System and simulation: Concept of system and elements of system, Discrete and continuous system, Models of system and Principles of modeling and simulation, Monte carlo simulation, Types of simulation, Steps in simulation model, Advantages, limitations and applications of simulation, Applications of simulation in manufacturing system

Review of statistics and probability: Types of discrete and continuous probability distributions such as Geometric, Poisson, Uniform, Normal, Exponential distributions with examples.

Random numbers: Need for RNs, Technique for Random number generation such as Mid product method, Mid square method, and Linear congruential method with examples

Test for Random numbers: Uniformity - Chi square test or Kolmogorov Smirnov test, Independency- Auto correlation test

Random Variate generation: Technique for Random variate generation such as Inverse transforms technique or Rejection method

Analysis of simulation data: Input data analysis, Verification and validation of simulation models, Output data analysis

Simulation languages: History of simulation languages, Comparison and selection of simulation languages

Design and evaluation of simulation experiments: Development and analysis of simulation models using simulation language with different manufacturing systems

Queueing models: An introduction, M/M/1 and M/M/m Models with examples, Open Queueing and Closed queueing network with examples

Markov chain models and others: Discrete time markov chain with examples, Continues time markov chain with examples, stochastic process in manufacturing, Game theory

Learning Resources:

Text Books:

1. Discrete Event System Simulation", J.Banks, J.S. Carson, B. L. Nelson and D.M. Nicol, PHI, New Delhi, 2009.
2. Simulation Modeling and Analysis", A.M. Law and W.D.Kelton, Tata McGraw Hill Ltd, New Delhi, 2008.
3. Performance Modeling of Automated Manufacturing Systems", N. Viswanadham and Y. Narahari, PHI, New Delhi, 2007.

ME 5363	INTELLIGENT MANUFACTURING SYSTEMS	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Develop reachability graphs for various manufacturing system problems using petri net models
CO2	Develop knowledge representation to establish models for processing
CO3	Apply clustering techniques to identify the variations in information sharing
CO4	Apply machine learning techniques for various real life applications in manufacturing systems
CO5	Evaluate block chain technology in the context of manufacturing systems design

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	2		1
CO2			2	2	2	1
CO3	1		2	2		1
CO4	3	1	2	3		1
CO5	2	2	2	3		

Syllabus:

Petri Nets: Key concepts and definitions, principles of net theory, Place/Transition Systems and Elementary Net (EN) Systems. Token game, reachability, state graph, behavioural properties like deadlock and boundedness, behavioural equivalence and normal forms. Elementary Net Systems: Causality, conflict, concurrency, and confusion. Examples of Petri net models. Examples in manufacturing Systems

Components of Knowledge Based Systems: Basic Components of Knowledge Based Systems, Knowledge Representation, Comparison of Knowledge Representation Schemes, Interference Engine, Knowledge Acquisition, Clustering. Examples in manufacturing Systems Cloud Manufacturing and Networking with TCP/IP: Introduction to cloud computing: cloud models, cloud service examples, cloud based services & applications. Introducing TCP/IP, IP Addressing and Related Topics, Data Link and Network Layer TCP/IP Protocols, Internet Control Message Protocol (ICMP), Transport Layer TCP/IP Protocols, Basic TCP/IP Services.

Machine Learning: Machine Learning – Concept, Artificial Neural Networks, Biological and Artificial Neuron, Deep Nets, Applications in manufacturing; Use of probability and fuzzy logic for machine thinking, Examples in manufacturing Systems.

Agent and Multi-agent systems: Agents, agent definitions and classification, multi-agent systems, Models of agency, architectures and languages, Agent communication and interaction protocols. Examples in manufacturing Systems

Block Chain Technology: Basic Concepts, Trust- The need for trust, Forms of trust, The problem space for block chain. Cryptography - Information security as a form of trust, Public and Private keys, Digital signatures, Hashing. Examples in manufacturing Systems

Learning Resources:

Text Books:

1. Automation, Production Systems and CIM", GrooverM.P.,Prentice-Hall, New Delhi, 2009.
2. A Comprehensive guide to AI and Expert Systems", Robert Levine , McGraw Hill Inc, 1986.
3. Automation, Production Systems and Computer Integrated Manufacturing", Mikell P. Groover, PHI, 2008, 8th edition.
4. Guide to TCP/IP, Ed Tittel, Laura Chappell, Third Edition. Course Technology Incorporated, 2007,
5. Automated Planning- Theory and Practice, Malik Ghallab Malik, Morgan Kaufmann, 2004.
6. Machine Learning, Mitchell T, Mc-Graw Hill, 2012.

References:

1. https://www.anylogic.com/use-of-simulation/agent-based-modeling/
2. http://pipe2.sourceforge.net/
3. https://in.mathworks.com/content/dam/mathworks/ebook/gated/machine-learning-ebook-all- chapters.pdf
4. Intelligent Manufacturing Systems, Andrew Kusiak/Prentice Hall.

ME 5364	LEAN MANUFACTURING SYSTEMS	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Understand the concepts in Lean Manufacturing.
CO2	Understand the tools and methods of Lean Manufacturing.
CO3	Analyze the issues in Lean implementation.
CO4	Distinguish between Lean, TPS, ERP and ISO 9001:2000.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		2	2	1	
CO2			2	2	1	
CO3	2		2	2	2	2
CO4	2		2	2	3	1

Syllabus:

Introduction to lean manufacturing: Objectives of lean manufacturing-key principles and implications of lean manufacturing- traditional Vs lean manufacturing.

Lean manufacturing concepts: Value creation and waste elimination- main kinds of wastepull production-different models of pull production-continuous flow-continuous improvement / Kaizen- worker involvement -cellular layout- administrative lean.

Lean manufacturing tools and methodologies: Standard work -communication of standard work to employees -standard work and flexibility -visual controls-quality at the source- 5S principles preventative maintenance-total quality management-total productive maintenance changeover/setup time -batch size reduction -production leveling.

Value stream mapping: The as-is diagram-the future state map-application to the factory simulation scenario-line balancing -Poke Yoke -Kanban – overall equipment effectiveness.

Just in time manufacturing: Introduction - elements of JIT - uniform production rate - pull versus push method- Kanban system - small lot size - quick, inexpensive set-up - continuous improvement. Optimised production technology.

One-piece flow: Process razing techniques – cells for assembly line – case studies.

Implementing lean: Road map-senior management Involvement-best practices

Reconciling lean with other systems: Toyota production system-lean six sigma-lean and ERP lean with ISO9001:2000.

Learning Resources:

Text Books:

1. Design and Analysis of Lean Production Systems, Askin R G and Goldberg J B, John Wiley and Sons Inc., 2003.
2. Lean Tools: A Pocket Guide to Implementing Lean Practices, Micheal Wader, Productivity and Quality Publishing Pvt Ltd, 2002.
3. Operations Management for Competitive Advantage, Richard B Chase F Robert Jacobs and Nicholas J Aquilano, 10th Edition, McGraw Hill/Irwin, 2003.
4. The Toyota Leaders – An Executive Guide, Masaaki Sato, Vertical Inc, New York, 2008.

ME 5365	SUSTAINABLE MANUFACTURING	3-0-0: 3

Pre-requisites:

Course Outcomes:

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

CO1	Understand the concept of sustainable manufacturing relates to current technologies and manufacturing decisions
CO2	Perform carbon footprint analysis and Life Cycle Assessment (LCA) specific to manufacturing systems and processes.
CO3	Develop Green Manufacturing process, Lean manufacturing and Green supply chain techniques
CO4	Evaluate the economics and environmental impact of sustainable manufacturing alternatives – Case studies.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2	2	2	
CO2	2		2	2	2	
CO3	2	2	2	2	2	
CO4	3	2	2	2	2	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Concept of sustainability, manufacturing, operations, processes, practices, Resources in manufacturing, five Ms, system approach to manufacturing, Basic experimental design, factor identification, quantification, comparison, Motivations and Barriers to Green Manufacturing, Environmental Impact of Manufacturing, Strategies for Green Manufacturing. Metrics for Green Manufacturing, Metrics Development Methodologies.

Circular Economy & Manufacturing: Introduction to CE concepts, Limits of Linear combustion, Butterfly Model of circular manufacturing, Biological nutrients & Technical Nutrients, Building blocks of Circular manufacturing, Impacts of Circular manufacturing, Reike's CBM archetype, case studies on Automobile Industry, Food Industry etc.

Management of waste & pollution: Types, sources and nature of wastes, waste processing, green processing & engineering operations, Energy recovery, and 3 R& 6 R principle. Types of pollution and management-Anti pollution approaches & guide lines.

Environment friendly materials: Materials for sustainability, eco-friendly and new age energy efficient and smart materials, alternative manufacturing practices, materials and selection of manufacturing processes, control on use of renewable materials, Bio-degradable materials recycling of materials.

Sustainable Manufacturing Tools: Principles of green manufacturing and its efficiency, Green manufacturing and sustainability, System model architecture and module, Design and planning, control or tools for green manufacturing (Qualitative Analysis), Consumption Analysis, Life Cycle Analysis, Efficiency, Sustainability tools). Standards for green manufacturing (ISO 14000 and OHSAS 18000), Waste stream mapping and application,

Design for environment and for sustainability – Discuss the Product Life Cycle of manufactured goods.

Life Cycle Analysis: Remanufacture and disposal, Tools for LCA, Optimization for achieving sustainability in unit manufacturing, Green manufacturing Lean models, value analysis, carbon footprint, analysis for carbon footprint Green manufacturing: sustainability framework Green manufacturing techniques: factors effecting sustainability.

Green manufacturing techniques: Dry and near-dry machining, edible oil based cutting fluids Green manufacturing techniques: cryogenic machining for eco-efficiency Green manufacturing, Lean manufacturing, Lean techniques for green manufacturing Waste assessment and strategies for waste reduction in green manufacturing, Reconfigurable manufacturing systems

Green Supply Chain: Carbon footprints in transportation Green Supply chain: techniques and implementation Green Supply chain, Logistics management Green Supply Chain as Product Life Cycle Management, Servitization. Case Studies: Green packaging and supply chain, implementation of lean manufacturing at industries

Learning Resources:

Text Books:

1. Montgomery Douglas, 2017. Design of Experiments, John Wiley and Sons, Inc.
2. Dornfeld, D.A. ed., 2012. Green manufacturing: fundamentals and applications. Springer Science & Business Media.
3. Ashby, M. F. Materials and the environment: eco-informed material choice. Elsevier, 2012.

References :

1. Klemes, J., 2011. Sustainability in the process industry. McGraw-Hill. 2011
2. M.Karpagam, GeethaJaikumar,Green Management ,Ane Books Pvt.Ltd. 2010
3. M.K. Ghosh Roy,Design for Environment: A guide to sustainable Product Development Sustainable Development, Ane Books Pvt.Ltd,2009

Online :

1. www.ellenmacarthurfoundation.org

ME 5366	PRODUCT LIFE CYCLE MANAGEMENT	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

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

CO1	Understand product data, information, structures and PLM concepts.
CO2	Apply PLM systems in organization verticals including production, after sales, sales and marketing, and subcontracting.
CO3	Measure benefits of PLM implementation in daily operations, material costs, productivity of labour and quality costs.
CO4	Apply PLM concepts for service industry and E-Business.
CO5	Recognize tools and standards in PLM.
CO6	Propose implementation methods to deploy a PLM system in a global company

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2	2		
CO2	2	2	2	2	2	2
CO3	3	2	2	2	3	2
CO4	3	2	2	2	3	2
CO5	3		2	2	3	
CO6	3		2	2	3	

Detailed syllabus:

Fundamentals of PLM: Product data or Product information, Product lifecycle management concept, The P L and M of PLM –PLM Paradigm –The PLM Environment – Issues in traditional environment – Product Data Issues – Product Pains - Opportunities

Business Processes in the PLM Environment – Introduction – Process reality in a typical company – Business process activities in a PLM initiative **-**Business process improvement approaches - Configuration Management – Engineering Change Management

Product Structures: Standardized product data and materials data model, KPIs for product data – Generic issues with product data – Product data activities in the PLM initiative.

PLM service information model: Categorizing services, Rational for building service products, How to make a service more like a tangible product?, Making items out of product functions, PLM challenges in service business, An IT-service provider and a customer-specifically variable product.

Integration of the PLM system with other applications: Different ways to integrate PLM systems, Goal of integrating PLM, SCM and ERP – Digital Transformation of PLM -IoT in Manufacturing – Convergence of PLM with IIoT.

Implementing end to end business process management: Product lifecycle management as a business strategy tool, Product lifecycle management as an enabler of cooperation

between companies, Contents of collaboration, Successful cooperation, Tools of collaboration, From changes in the business environment to product strategy, Business Benefits of PLM.

PLM applications in process and product industries examples: Case 1: Electronics manufacturer, Case 2: An engineering product, Case 3: Capital goods manufacturer and customer-specifically variable product, Case 4: An IT-service provider and a customer-specifically variable product. Case Studies with Siemens Teamcenter PLM or similar softwares.

Learning Resources:

Text Books:

1. Product Lifecycle Management (Volume 1): 21st Century Paradigm for Product Realisation (Decision Engineering), John Stark, Springer, 2020.
2. Product Lifecycle Management, AnttiSaaksvuori, AnselmiImmonen, Third Edition, Springer, 2008.
3. SOA approach to Enterprise Integration for Product Lifecycle, IBM Red books, 2011.
4. Product Life Cycle Management (PLM), A Digital Journey using Industrial Internet of Things, Udhayan Elongovan, CRC Press, 2020

Reference Books:

1. John Stark, Product Lifecycle Management (Volume 2): The Devil is in the Details, Springer, 2016.
2. John Stark, Product Lifecycle Management (Volume 4): The Case Studies (Decision Engineering), Springer, 2016.
3. Anthony A. Atkinson, Management Accounting, 6th Edition, Prentice Hall, Inc., 2012
4. Cecil B. Bozarth, Robert B. Handfield, Introduction to Operations and Supply Chain Management, 5th Edition, Pearson, 2019.

ME 5367	RELIABILITY ENGINEERING	3-0-0: 3

Pre-requisites:

Course Outcomes:

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

CO1	Understand the concepts of Reliability, Availability and Maintainability
CO2	Develop hazard-rate models to know the behaviour of components.
CO3	Build system reliability models for different configurations.
CO4	Assess reliability of components & systems using field & test data.
CO5	Implement strategies for improving reliability of repairable and non-repairable systems.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			2	2		
CO2	2		2	2		
CO3	2		2	2	2	
CO4	3	2	2	3		
CO5	2	2	2	2	2	

Syllabus:

Introduction: Probabilistic reliability, failures and failure modes, repairable and non-repairable items, pattern of failures with time, reliability economics.

Component Reliability Models: Basics of probability & statistics, hazard rate & failure rate, constant hazard rate model, increasing hazard rate models, decreasing hazard rate model, time-dependent & stress-dependent hazard models, bath-tub curve.

System Reliability Models: Systems with components in series, systems with parallel components, combined series-parallel systems, k-out-of-m systems, standby models, load-sharing models, stress-strength models, reliability block diagram.

Life Testing & Reliability Assessment: Censored and uncensored field data, burn-in testing, acceptance testing, accelerated testing, identifying failure distributions & estimation of parameters, reliability assessment of components and systems.

Reliability Analysis & Allocation: Reliability specification and allocation, failure modes and effects and criticality analysis (FMECA), fault tree analysis, cut sets & tie sets approaches;

Maintainability Analysis: Repair time distribution, MTBF, MTTR, availability, maintainability, preventive maintenance.

Text Books:

1. An Introduction to Reliability and Maintainability Engineering, Ebeling CE, TMH, New Delhi, 2004.
2. Practical Reliability Engineering, O'Connor P and Kleymer A, Wiley, 2012

ME 5368	INDUSTRY 4.0 AND IIoT	3-0-0: 3

Pre-requisites: Nil

Course Outcomes:

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

CO1	Explore how Industry 4.0 will change the current manufacturing technologies and processes by digitizing the value chain
CO2	Understand the drivers and enablers of Industry 4.0
CO3	Learn about various IIoT-related protocols
CO4	Build simple IIoT Systems using Arduino and Raspberry Pi

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		3	1	2	
CO2	2		2	2	1	
CO3	2		3	3		
CO4			3	3	1	2

Syllabus:

Introduction to Industry 4.0: Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Mass Customization, Smart and Connected Business Perspective, Smart Factories, Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence, Big Data and Advanced Analysis

Introduction to IIoT: Architectural Overview, Design principles and needed capabilities, IoT Applications, Sensing, Actuation, Basics of Networking, M2M and IoT Technology Fundamentals- Devices and gateways, Data management, Business processes in IoT, Everything as a Service (XaaS), Role of Cloud in IoT, Security aspects in IoT.

Elements of IIoT: Hardware Components- Computing (Arduino, Raspberry Pi), Communication, Sensing, Actuation, I/O interfaces. Software Components- Programming API's (using Python/Node.js/Arduino) for Communication Protocols-MQTT, ZigBee, Bluetooth, CoAP, UDP, TCP.

IIoT Application Development: Solution framework for IoT applications- Implementation of Device integration, Data acquisition and integration, Device data storage- Unstructured data storage on cloud/local server, Authentication, authorization of devices. Case Studies: IoT case studies and mini projects based on Industrial automation, Transportation, Agriculture, Healthcare, Home Automation.

Learning Resources:

Text Books:

1. Introduction to Industrial Internet of Things and Industry 4.0, Sudip Misra, Chandana Roy, Anandarup Mukherjee, CRC Press, 2020.
2. A Hands on Approach", Vijay Madisetti, Arshdeep Bahga, Ïnternet of Things, University Press, 2009.
3. Introduction to Internet of Things: A practical Approach", Dr. SRN Reddy, RachitThukral and Manasi Mishra, ETI Labs,2010
4. The Internet of Things: Enabling Technologies, Platforms, and Use Cases", Pethuru Raj and Anupama C. Raman, CRC Press, 2012
5. Designing the Internet of Things", Adrian McEwen, Wiley, 2015

Reference Books:

1. Internet of Things: Architecture and Design, Raj Kamal, McGraw Hill., 2005.
2. Getting Started with the Internet of Things, CunoPfister, O Reilly Media, 2007.

Online :

1. https://onlinecourses.nptel.ac.in/noc21_cs17/preview

ME 5369	DESIGN AND ANALYSIS OF EXPERIMENTS	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Formulate objective(s) and identify key factors in designing experiments for a given problem.
CO2	Develop appropriate experimental design to conduct experiments for a given problem.
CO3	Analyze experimental data to derive valid conclusions.
CO4	Optimize process conditions by developing empirical models using experimental data.
CO5	Design robust products and processes using parameter design approach.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	2		1
CO2	3		2	3		1
CO3	3	1	2	3		1
CO4	3		2	3		1
CO5	2		2	3		1

Syllabus:

Fundamentals of Experimentation: Role of experimentation in rapid scientific progress, Historical perspective of experimental approaches, Steps in experimentation, Principles of experimentation; Simple Comparative Experiments: Basic concepts of probability and statistics, Comparison of two means and two variances, Comparison of multiple (more than two) means & ANOVA;

Experimental Designs: Factorial designs, fractional factorial designs, orthogonal arrays, standard orthogonal arrays & interaction tables, modifying the orthogonal arrays, selection of suitable orthogonal array design, analysis of experimental data;

Response Surface Methodology: Concept, linear model, steepest ascent, second order model, regression;

Taguchi's Parameter Design: Concept of robustness, noise factors, objective function & S/N ratios, inner-array and outer-array design, data analysis

Learning Resources:

Text Books:

1.Design and Analysis of Experiments, Montgomery DC, 7th Edition, John Wiley & Sons, NY, 2008

2.Taguchi Techniques for Quality Engineering, Ross PJ, McGraw-Hill Book Company, NY, 2008.

ME 5370	PROJECT MANAGEMENT	3-0-0: 3

Pre-requisites:

Course Outcomes:

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

CO1	Understand the importance of projects and its phases.
CO2	Analyze projects from marketing, operational and financial perspectives.
CO3	Evaluate projects based on discount and non-discount methods.
CO4	Develop network diagrams for planning and execution of a given project.
CO5	Apply crashing procedures for time and cost optimization.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		2	2		2
CO2	3	1	2	2		2
CO3	2	1	2			2
CO4	2	1	2	2	2	2
CO5	2	1	2	2		2

Syllabus:

Introduction: Introduction to Project Management, History of Project Management, Project Life Cycle.

Project Analysis: Facets of Project Analysis, Strategy and Resource Allocation, Market and Demand Analysis, Technical Analysis, Economic and Ecological Analysis.

Financial Analysis: Financial Estimates and Projections, Investment Criteria, Financing of Projects.

Network Methods in PM: Origin of Network Techniques, AON and AOA differentiation, CPM network, PERT network, other network models.

Optimization in PM: Time and Cost trade-off in CPM, Crashing procedure, Scheduling when resources are limited.

Project Risk Management: Scope Management, Work Breakdown Structure, Earned Value Management, Project Risk Management.

Text Books:

1. Project: A Planning Analysis, Prasanna Chandra, Tata McGraw Hill Book Company, New Delhi, 4th Edition,2009.
2. Project Management, Cleland, Gray and Laudon, Tata McGraw Hill Book Company, New Delhi, 3rd Edition, 2007.
3. Larson Project Management , Clifford F. Gray, Gautam V. Desai, Erik W., Tata McGraw-Hill Education, 2010

ME 5371	ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING FOR MECHANICAL SYTEMS	3-0-0: 3

Pre-Requisites: Nil

Course Outcomes:

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

CO1	Understand the core concepts of Mechanical Systems in the context of Industry 4.0
CO2	Apply AI, ML and Deep Learning concepts on Various Mechanical Systems
CO3	Apply the statistical and optimization techniques on Mechanical Systems
CO4	Evaluate the Mechanical System performance using simulation and experimental analysis

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3		3	3
CO2			3	3		3
CO3	3	3	3	3		3
CO4		3		3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Mechanical Systems evolution in the context of Industry 4.0, Key issues: Adaptability, Intelligence, Autonomy, Safety, Sustainability, Interoperability, Flexibility of Mechanical Systems.

Introduction of Statistics; Descriptive statistics: Central tendency measures, Dispersion measures, data distributions, centre limit theorem, sampling, sampling methods; Inferential Statistics: Hypothesis testing, confidence level, degree of freedom, P-value, Chi-square test, ANOVA, Correlation V's Regression, Uses of Correlation and regression.

Artificial Intelligence: Brief review of AI history, Problem formulation: Graph structure, Graph implementation, state space representation, search graph and search tree, Search Algorithms: random search, Depth-first, breadth-first search and uniform-cost search. Heuristic: Best first search, A* and AO* algorithm, generalization of search problems. Ontology; Fuzzy; Meta-heuristics.

Machine Learning: Overview of supervised and unsupervised learning; Supervised Learning: Linear Regression, Non-linear Regression Model evaluation methods, Logistic Regression, Neural Networks; Unsupervised Learning: K-means clustering, C-means Clustering. Convolutional Neural Networks (CNN), Pooling, Padding Operations, Interpretability in CNNs, Limitations in CNN. Cases with respect to different mechanical systems.

Introduction to Raspberry Pi; Installation of Raspbian OS on Raspberry Pi; Controlling LED using Raspberry Pi; Integrating IR Sensor with Raspberry Pi; Controlling LED with IR Sensor; Integrating Temperature and amp; Humidity Sensor with

Raspberry Pi read Current Environment Values, Collecting the sensor data using Raspberry Pi; Matlab toolboxes - Simulink, Mechanical Systems implementation: From features to software components, Mapping software components to ECUs.

Learning Resources

Text Books:

1. Rajkumar, Dionisio De Niz ,and Mark Klein, *Cyber-Physical Systems*, Wesley Professional.
2. Rajeev Alur, *Principles of Cyber-Physical Systems*, MIT Press, 2015.
3. Robert Levine et al., "*A Comprehensive guide to AI and Expert Systems*", McGraw Hill Inc, 1986.
4. E. A. Lee and S. A. Seshia, "Introduction to Embedded Systems: A Cyber-Physical Systems Approach", 2011.
5. C. Cassandras, S. Lafortune, "Introduction to Discrete Event Systems", Springer 2007.
6. Constance Heitmeyer and Dino Mandrioli, "Formal methods for real-time computing", Wiley publisher, 1996.
7. Montgomery Douglas, 2017. Design of Experiments, John Wiley and Sons, Inc.

ME 5403	MECHANICAL VIBRATIONS	3-0-0: 3

Course Out comes:

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

CO1	Analyze the causes and effects of vibrations in mechanical systems and identify discrete and continuous systems.
CO2	Model the physical systems into schematic models and formulate the governing equations of motion.
CO3	Compute the free and forced vibration responses of multi degree of freedom systems through modal analysis and interpret the results.
CO4	Analyse and design systems involving unbalances, transmissibility, vibration isolation and absorption.
CO5	Analyse and design to control and reduce vibration effects in machinery.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2		2	2
CO2	3	3	3		2	2
CO3	2	3	2	2	3	2
CO4	3	3	2		3	2
CO5	2	3	2	2	3	2

Syllabus:

Introduction: Causes and effects of vibration, Classification of vibrating system, Discrete and continuous systems, degrees of freedom, Identification of variables and Parameters, Linear and nonlinear systems, linearization of nonlinearsystems,Physicalmodels,SchematicmodelsandMathematicalmodels.

Single Degree of Freedom (SDF) systems: Formulation of equation of motion: Newton – Euler method, DeAlembert's method, Energy method, Free Vibration: Undamped Free vibration response, Damped Free vibration response, Case studies on formulation and response calculation. Forced vibration response of SDF systems: Response to harmonic excitations, solution of differential equation of motion, Vector approach, Complex frequency response, Magnification factor Resonance, Rotating/reciprocating un balances.

Dynamics of Rotors: Whirling of rotors, Computation of critical speeds, influence of bearings, Critical speeds of Multirotor systems.

Design case studies: Design case studies dealing with Transmissibility of forces and motion, Vehicular suspension, Analysis of Vehicles as single degree off reedom systems-vibration transmitteddduetounevennessoftheroads,preliminarydesignofautomobile suspension. Design of machine foundations and isolators.

Two degree of freedom systems: Introduction, Formulation of equation of motion:

Equilibriummethod,Lagrangianmethod,Casestudiesonformulationofequationsof motion, Free vibration response, Eigen values and Eigen vectors, Normal modes and mode superposition, Coordinate coupling, decoupling of equations of motion, Natural coordinates, Responsetoinitialconditions,coupledpendulum,freevibrationresponsecasestudies,Forced vibration response, Automobile as a two degree of freedom system –bouncing and pitching modes undamped vibration absorbers, Case studies on identification of system parameters and design of undamped vibration absorbers. Analysis and design of damped vibration absorbers.

Multi degree of freedom systems: Introduction, Formulation of equations of motion, Free vibration response, Natural modes and mode shapes, orthogonally of modal vectors, normalization of modal vectors, decoupling of modes, modal analysis, mode superposition technique, Free vibration response through modal analysis, Forced vibration analysis through modal analysis, Modal damping, Rayleigh's damping, Introduction to experimental modal analysis.

Continuous systems: Introduction to continuous systems, discretevs continuous systems, Exact and approximate solutions, free vibrations of bars and shafts, Free vibrations of beams, Forced vibrations of continuous systems Case studies, Approximate methods for continuous systems and introduction to Finite element method.

Vibration control in structures: Introduction, State space representation of equations of motion. Passive control, active control and semi active control, Free layer and constrained damping layers, Piezo electric sensors and actuators for active control, semi active control of automotive suspension systems.

Learning Resources:

1. Elements of Vibration Analysis, L.Meirovich, 2ndEd.TataMc-Grawhill,2007
2. MechanicalVibrations.SRao,4thEd., Pearson education,2011
3. Theory of Vibration, W.T,Thompson, CBS Publishers
4. Vibration: Fundamentals and Practice, Clarence W. DeSilva, CRCPressLLC,2000
5. Mechanical Vibrations, Venkatachalam R., PHI Publications,2018

ME 5452	FINITE ELEMENT ANALYSIS IN DESIGN	3-0-0: 3

Course Outcomes:

Attheendofthecourse,thestudentshallbeableto:

CO1	Make use of the concept of finite element method for solving machine design problems
CO2	Solve problems in 1-D structural systems involving bars, trusses, beams and frames.
CO3	Develop 2-D and 3-D FE formulations involving triangular, quadrilateral elements and higher order elements.
CO4	Apply the knowledge of FEM for stress analysis, model analysis, heat transfer analysis and flow analysis.
CO5	Develop algorithms and FE code for solving design problems and adapt commercial packages for complex problems.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		2		2	2
CO2	2		2		2	
CO3			2	2	3	
CO4	3		3	2	3	2
CO5	3	2	3	3	3	

Syllabus:

Introduction: Historical Perspective of FEM and applicability tomechanicalengineeringdesignproblems.

Mathematical Models and Approximations: Review of elasticity. Mathematical models for structural problems: Equilibrium of continuum-Differential formulation, Energy Approach-integral formulation: Principle of Virtual work-Variational formulation. Overview of approximate methods for the solution of the mathematical models, Residual methods and weighted residual methods, Ritz, Rayleigh-Ritz and Gelarkin's methods. Philosophy of solving continuum problems using Finite Element Method.

Finite Element Formulation: Generalized FE formulation based on weighted residual method and through minimization of potential, displacement based formulation, Concept of discretization, Interpolation, Formulation of Finite element characteristic matrices and vectors, Compatibility conditions, Assembly and boundary considerations.

Finite Element Analysis for One Dimensional Structural problems: Structural problems with one dimension algeometry. Bar element: formulation of stiffness matrix, consistent and lumped load vectors. Boundary conditions and their incorporation: Elimination method, Penalty

Method, Introduction to higher order elements and their advantages anddis advantages. Formulation for Truss elements, Case studies involving hand calculations with an emphasis on Assembly, boundary conditions,contactconditionsandmultipointconstraints.

BeamsandFrames: Reviewofbending ofbeams, higher order continuity (C^0andC^1Continuity),interpolationforbeamelementsandformulationofFEcharacteristics,Planeandspaceframesandexamplesproblemsinvolvinghandcalculations.Algorithmicapproachfordeveloping computercodesinvolving1-Delements.

Two dimensional Problems: Interpolation in two dimensions, naturalcoordinates,Isoparametricrepresentation,ConceptofJacobian.Finiteelementformulationfor plane stressplane strain and axi-symmetric problems; TriangularandQuadrilateral elements, higher order elements, sub-parametric, Isoparametricandsuperparametricelements. Formulation of plate bending elements using linear andhigher order bending theories,Shell elements,General considerationsin finite elementanalysis of design problems, Choosing an appropriate element and the solution strategies.Introductiontopreandpostprocessingoftheresultsandanalysis.

ThreeDimensional Problems: Finite element formulation for 3-D problems,meshpreparation,tetrahedralandhexahedralelements,casestudies.

DynamicAnalysis:FEformulationindynamicproblemsinstructuresusingLagrangianMethod,Consistentandlumpedmassmodels,Formulationofdynamicequationsofmotion,Modellingofstructural dampingandformulationofdampingmatrices,Modelanalysis,Modesuperpositionmethodsandreductiontechniques.

FEMinHeat Transferand Fluid Mechanics problems: Finiteelementsolutionfor one dimensional heat conduction with convective boundaries. Formulationofelement characteristics and simple numerical problems.Formulation for 2-D and 3-Dheatconductionproblemswithconvectiveboundaries.Introductiontothermo-elasticcontact problems. Finite element applicationsin potential flows; Formulationbased onPotentialfunctionandstreamfunction.Casestudies.

AlgorithmicApproachforproblemsolving: Algorithmicapproachfor Finiteelement formulation of element characteristics, Assembly and incorporation of boundaryconditions. Guidelinesforcodedevelopment.IntroductiontocommercialFiniteElementsoftwarepackageslikeANSYS.

Learning Resources:

1. FiniteelementMethodinEngineering,SingiresuS.Rao,5ed,Elsevier,2012.
2. TextbookofFiniteElementAnalysis,SeshuP,PHI.2004
3. FiniteElementMethodin Engineering,Reddy,J.N.,TataMcGrawHill,2017
4. TheFiniteElementMethod4Volset,Zeincowicz,4thEdition,Elsevier2007.

ME 5466	TRIBOLOGY IN DESIGN	3-0-0: 3

CourseOutcomes:

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

CO1	Analyze properties of lubricant and select proper lubricant for a given application.
CO2	Identify tribological performance parameters of sliding contact in different lubrication regimes
CO3	Design and select appropriate bearings for a given application
CO4	Predict the type of wear and volume of wear in metallic and polymer surfaces.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	2		2
CO2	3	3	3	3	2	
CO3	3	2	3	2	3	2
CO4	3		3	2	2	2

Syllabus:

Introduction: Overview of the course, history and basic concept of friction, wear and lubrication.
Introduction to Concept of tribo design: Specific principles of tribo design; Tribological problems in machine design: Plain sliding bearings, Rolling contact bearings, Piston, piston rings and cylinder liners, Cam and cam followers, Friction drives, Involute gears, Hypoid gears, Worm gears, Seals.

Friction and Wear: Origins of sliding friction: Contact between bodies in relative motion, Friction due to adhesion, Friction due to ploughing, Friction due to deformation, Energy dissipation during friction, Friction under complex motion conditions, Types of wear and their mechanisms: Adhesive wear, Abrasive wear, Wear due to surface fatigue, Wear due to chemical reactions, Sliding contact between surface asperities, Wear and friction of metallic, polymeric and ceramic composite materials

Lubrication modes and Theories of hydrodynamic lubrication: Lubricants-Types of lubricants, Objectives of lubricant, Physical properties of lubricants, Selection of lubricant.
Modes of lubrication - hydrodynamic, hydrostatic, Elasto-hydrodynamic, mixed and boundary lubrication, Reynolds' equation, Applications of hydrodynamic lubrication theory -Journal bearing and Inclined thrust padbearing, Hydrodynamic lubrication of roughened surfaces, Theories of Externally pressurized lubrication, Squeeze-film lubrication, Elasto-hydrodynamic lubrication and air lubricated bearing.

Lubrication regimes and bearings design: Rheological lubrication regime, Functional lubrication regime, Bearing types and its selection. Bearings design.

Tribo Design of Machine Elements: Lower Kinematic pairs – Sliding bearings, mechanical face seal, clutches and brakes; Higher Kinematic pairs – Ball bearing, Roller bearing, Gear contacts. Case studies.

Learning Resources:

1. Engineering Tribology, Stachowaik, G.W.,Batchelor, A.W.,3rdEd., Elsevier, 2010.
2. Tribology in Machine Design, TA Stolarski, Butterworth-Heinemann, 2000.
3. Engineering Tribology, Williams J A,OxfordUniv. Press,2001.
4. Introduction to bearings, Majumdar B.C,S.Chand&Co.,Wheelerpublishing,1999.
5. Fluid film lubrication theory and design, Andras Z. Szeri, Cambridge Universitypress,1998.
6. Basic lubrication theory, Cameron A, EllisHorwood Ltd.,2002.
7. Tribology Hand Book, NealeMJ,CBSPublications,2012.
8. Mechanical Vibrations, Venkatachalam R.,PHI Publications, 2018

ME 5467	ADVANCED COMPOSITE TECHNOLOGIES	3-0-0: 3

CourseOutcomes:

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

CO1	Understand composite material and their reinforcements
CO2	Select constituent materials to develop appropriate composites
CO3	Analyze interfaces of composites for predicting their mechanical properties.
CO4	Develop metal matrix, ceramic matrix and polymer matrix composites with calculated values of constituents
CO5	Analyze the performance of composites

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	2	3	3
CO2	3	2	2	2	2	2
CO3	3	3		3		2
CO4	3	3	2	2	2	3
CO5	3	3	2	2	2	3

Syllabus:

Introduction: Overview of the course, history and basic concept of composites, Types and constituents, reinforcement and matrices, interface and mechanism of strengthening.

Fundamental concepts: Definition and Classification of Composites, particulate and dispersion hardened composites, continuous and discontinuous fibre reinforced composites MMC, PMC, CMC.

Metal Matrix Composites Processing: Liquid state processes, solid state processes and in situ processes.

Interface: Role, reactions, bonding mechanisms and bond strength.

Properties and applications: Strength, stiffness, creep, fatigue and fracture; thermal, damping and tribological properties.

Polymer Matrix Composites Processing: Hand layup and spray technique, filament winding, pultrusion, resin transfer molding, bag and injection molding, sheet molding compound. Matrix resins-thermoplastics and thermosetting matrix resins. Reinforcing fibers- Natural fibers (cellulose, jute, coir etc.), carbon fiber, glass fiber, Kevlar fiber, etc. Particulate fillers-importance of particle shape and size. Coupling agents-surface treatment of filler sand fibers, significance of interface in composites. short and continuous fibre reinforced composites, critical fibre length, and anisotropic behavior.

Ceramic Matrix Composites Processing: Cold pressing & sintering, hot pressing reaction

bonding processes, infiltration, in-situ chemical reaction, Sol-Gel and polymer pyrolysis, self-propagating high temperature synthesis. Carbon-carbon composites, Interfaces.

Rule of mixtures. Stress, strain transformations.

Nanocomposites: Introduction to Nanocomposites, advantages disadvantages

Test methods: Quality assessment, physical and mechanical property characterization.

Learning Resources:

1. Composite Materials Science and Engineering, Chawla, Springer
2. An introduction to composite materials, Hull, Cambridge
3. ASM Handbook Composites, Steven L.Donaldson,Volume21,2001.
4. Composite Materials, Science and Engineering, Krishan K.Chawla,Springer,2001.
5. Process Modelling in Composites Manufacturing, Suresh G. Advani, E. Murat Sozer, 2ndEd. CRC Press, 2009

ME 5468	ROBOTICS	3-0-0: 3

CourseOutcomes:

At the end ofthe course, the student shall beableto:

CO1	Classify robots based on joints and arm configurations.
CO2	Design application specific End Effectors for robots.
CO3	Compute forward and inverse kinematics of robots and determine trajectory plan.
CO4	Program robot to perform ypical tasks including Pick and Place, Stacking and Welding
CO5	Design and select robots for Industrial and Non-Industrial applications.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			2	2	3	2
CO2	2		3	2	3	2
CO3	2		2	2	2	2
CO4	2		2	2	2	2
CO5	3	1	3	3	3	2

Syllabus:

Introduction: Multibody systems, Automation, Classification of robots, Anatomy, Sensors (velocity, proximity, touch, torque etc), Grippers, selection of Robot based on the Application. Demonstration of different types of Robots & tools using Robot Simulator Software like ROBODK.

Kinematics: Manipulators Kinematics, Rotation Matrix, Homogenous Transformation Matrix, Direct and Inverse Kinematics for industrial robots for Position and orientation. Demonstrate FK and IK using simulation tools.

Differential Kinematics, statics and Dynamics: Jacobian, Lagrangian Formulation, Newton-Euler Formulation for RR &RP Manipulators. Demonstrate differential kinematics using simulation tools.

Trajectory planning & Control: Motion Control-Interaction control, Rigid Body mechanics, Control architecture- position, path velocity and force control systems, computed torque control, adaptive control, and Servo system for robot control. Demonstrate trajectory planning using simulation tools.

Advanced Topics in Robotics: Motion Planning (Methods of Path planners), Robot Vision (Feature Detection & Matching, Motion Tracking, Machine Learning methods).

Programming of Robots: Overview of various programming languages.

Application of Robots in production systems: Application of robot in welding, machine tools, material handling, and assembly operations parts sorting and parts inspection.

Learning Resources:

1. Robotics control, Sensing, Vision and Intelligence, Fu,K.S.,Gonzalez,R.C.,andLee,C.S.G.,McGraw-Hill Publishingcompany,New Delhi, 2003.
2. Engineering: An Integrated Approach, PrenticeHall of India, Klafter,R.D.,Chmielewski,T.A.,and Negin.M,RobotNew Delhi, 2002.
3. Introduction to Robotics Mechanics andControl,Craig,J.J.,AddisonWesley,1999.
4. Modern Robotics: Mechanics, Kevin M. Lynch, Frank C. Park, Planning, and Control, Cambridge University Press, 2017.

Online Resources:

1. nptel Courses: https://nptel.ac.in/courses/107/106/107106090/ , https://nptel.ac.in/courses/112/101/112101098/, https://nptel.ac.in/courses/112/107/112107289/, https://nptel.ac.in/courses/112/104/112104298/
2. Stanford Lecture Series: https://see.stanford.edu/Course/CS223A
3. MIT OCW: https://ocw.mit.edu/courses/mechanical-engineering/2-12-introduction-to-robotics-fall-2005/

ME 5469	OPTIMIZATION METHODS FOR ENGINEERING DESIGN	3-0-0: 3

CourseOutcomes:

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

CO1	Formulate a design task as an optimization problem
CO2	Identify constrained and unconstrained optimization problems and solve using corresponding methods
CO3	Solve discontinuous optimization problems using special methods
CO4	Solve non linear optimization problems with evolutionary methods

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	1	2
CO2	2	2	3	3	2	2
CO3	3		3	3	3	2
CO4	3		3	3	3	2

Syllabus:

Introduction to Optimization in Design: Problem formulation, OptimizationproblemsinMechanicalEngineering,Classificationofmethodsforoptimization

Single-variable Optimization: Optimal criteria, Derivative-free methods(bracketing, regionelimination),Derivativebasedmethods,root-findingmethods.

Multiple-variable Optimization: Optimal criteria, Direct search methods (Box's,Simplex, Hooke-Jeeves, Conjugate methods), Gradient-based methods (SteepestDescent,Newton's,Marquardt's,DFPmethod).FormulationandCasestudies.

Constrained Optimization: KKT conditions, Penalty method, Sensitivity analysis, Direct search methods for constrained optimization, quadratic programming, GRGmethod, Formulation and Casestudies.
Specialized algorithms: Integerprogramming (Penalty function and branch-and-bound method), Geometric programming.

Evolutionary Optimization algorithm: Genetic algorithms, simulated annealing, Anti-colony optimization, Particle swarm optimization.

Multi-objective Optimization: Terminology and concepts, the concepts of Paretooptimality and Paretooptimalset, formulation of multi-objective optimization problem, NSGA.

Casestudies and Computer Implementation: Representative case studies for important methods and development of computer code for the same to solve problems.

Learning Resources:

1. Introduction to Optimum Design, Jasbir Arora, AcademicPress,2004
2. Optimization For Engineering Design: Algorithms and Examples, Kalyanmoy Deb, PHI, 2004.
3. Multi-Objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, Wiley,2001.

ME5611	SURFACE ENGINEERING	3-0-0: 3

Pre-Requisites:Nil

Course Outcomes:

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

CO1	Understand the micro mechanisms involved in failure at different service conditions.
CO2	Identify the materials for surface engineering and characteristics.
CO3	Understand the fundamentals of basic surface modification techniques.
CO4	Select thick and thin layer coating technology to enhance the surface properties.
CO5	Evaluate the metallurgical, mechanical and tribological properties of engineered surfaces.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		3	3	2	
CO2	2		3	3	2	
CO3	3		3	3	2	
CO4	3		3	3	2	
CO5	3		3	3	2	

Syllabus:

Introduction: Concept and Importance, classification of surface modification techniques, advantages and their limitations.

Surface Degradation: Causes, types and consequences of surface degradation, Forms of wear – adhesive, abrasive, surface fatigue, corrosive, fretting and erosive wear, Classical governing laws related to wear, techniques to evaluate the wear damage.

Materials for Surface Engineering: Materials characteristics, their importance in surface engineering, wear resistant materials, selection of materials for engineering the surfaces for specific applications, New coating concepts including multi-layer structures, functionally gradient materials (FGMs), intermetallic barrier coatings and thermal barrier coating, Presurface treatment.

Conventional surface engineering practice: Surface engineering by material removal: like etching, grinding, polishing, etc. Surface engineering by material addition: like hot dipping, Electro-plating, carburizing, Cyaniding, etc.

Coating based Surface Modification Techniques: Principles and application of weld surfacing: SMAW, SAW, GMAW, Thermal spraying – flame spraying, electric arc spraying, plasma spraying, detonation gun spraying and high velocity oxy fuel spraying, Cold-Gas Spraying Method(CGSM), Principles, Process Parameters, Coating Properties.

Irradiation based and beam based techniques: Laser cladding, alloying, glazing, laser and induction hardening, heat treatment of steel and remelting by laser / TIG. Microwave glazing.

Thin Film coating techniques: Ion implantation, chemical vapour deposition (CVD) and physical vapour deposition (PVD), carburizing, nitriding, plasma nitriding, cyaniding.

Post-Spray Treatment: Heat Treatment, Electromagnetic Treatment, Furnace Treatment, HotIsostatic Pressing (HIP), Combustion Flame Re-melting, Impregnation Inorganic Sealants Organic Sealants Finishing Grinding Polishing and Lapping.

Characterization of coatings and surfaces: Measurement of coatings thickness, porosity &adhesion of surface coatings, Measurement of residual stress & stability, Surface microscopy, topography and Spectroscopic analysis of modified surfaces.

Learning Resources:

Text Books:

1. "Surface engineering: Enhancing the life of tribological components" Dheerendra Kumar Dwivedi. Springer, New Delhi, 2018.
2. Surface Engineering D.Srinivasa Rao, Daya Publishing House, 2017.

Reference Books:

1. Surface Engineering for Corrosion and Wear Resistance by J.R. Davis, ASM International, 2001.

2. ASM Hand book – Surface Engineering, ASM International, vol. 5, 9th edition, 1994.

3. Surface Engineering for Wear Resistances by K.G. Budinski. Prentice Hall Publisher, 1988.

Online Resources:

1. https://nptel.ac.in/courses/113/105/113105086/
2. https://nptel.ac.in/courses/112/107/112107248/

ME 5664	NON-DESTRUCTIVE TESTING AND EVALAUTION	3-0-0: 3

Pre-Requisites: Nil

Course Outcomes:

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

CO1	Understand the principles of NDT methods
CO2	Identify appropriate non-destructive testing methods for failure identification
CO3	Utilize radiography to identify underlying failure site
CO4	Analyse flaws using advanced eddy current methods
CO5	Utilize acoustic emission to identify leaks

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			3	3	2	
CO2			3	3	3	
CO3	3		3	3	3	
CO4	3		3	3	3	
CO5	3		3	3	3	

Syllabus:

Introduction to NDT, Liquid penetrant test: Physical Principles, Procedure for penetrant testing, penetrant testing materials, Penetrant testing methods, sensitivity, Applications and limitations, typical examples.

Ultrasonic testing: Basic properties of sound beam, Ultrasonic transducers, Inspection methods, Techniques for normal beam inspection, Techniques for angle beam inspection, Flaw characterization techniques, Applications of ultrasonic testing, Advantages and limitations.

Thermography: Basic principles, Detectors and equipment, techniques, applications.

Radiography: Basic principle, Electromagnetic radiation sources, radiographic imaging, Inspection techniques, applications, limitations, typical examples.

Eddy current test: Principles, instrumentation for ECT, techniques, sensitivity, advanced eddy Current test methods, applications, limitations.

Acoustic emission: Principle of AET, Technique, instrumentation, sensitivity, applications, Acoustic emission technique for leak detection.

Magnetic particle inspection: Principle of MPT, Procedure used for testing a component, sensitivity, limitations.

NDT of Composites: Codes and Conventions - Difficulties - Few Case Studies.

Learning Resources:

Text Books:

1. Non Destructive Evaluation: Theory, Techniques and Applications, Peter J. Shull , Marcel Dekkar, 2002.
2. Non Destructive Testing Hand Book, Vol. 4, P. McIntire (Ed.), American Society for Non Destructive Society, 2010

Reference Books:

1. Non Destructive Testing and Quality Control, ASM Metals Hand Book, Vol. 17, ASM, 1989.

ME 5761	ADDITIVE MANUFACTURING IN MEDICAL APPLICATIONS	3-0-0: 3

Pre-requisites: -NIL-

Course Outcomes:

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

CO1	Apply the concepts of medical imaging and 3D scanning for accurate 3D model re-construction
CO2	Identify the errors during processing of medical image data and minimize them
CO3	Select the suitable material for a given medical application
CO4	Analyze and select an additive manufacturing technology for a given medical application
CO5	Design and fabricate customized implant for the given medical application

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	2	2
CO2	3	2	3	2	2	2
CO3	3	2	3	2	2	2
CO4	3	2	3	2	2	2
CO5	3	2	3	2	2	2

Detailed Syllabus:

3-Dimensional Data Capture and Medical Scanning Technologies: Introduction to medical imaging, Human Anatomy, X-Ray technology, Computed Tomography (CT), Basic Components of CT, Different Types of CT Scanners, Magnetic Resonance Imaging (MRI), Ultrasound imaging, 3-D laser scanners, Industrial CT Scanners, 3D reconstruction and Reverse Engineering (RE), Image Reconstruction Procedure, Digital Communication in Medicine (DICOM) format, Types of Artifacts.

Medical Image Processing Software Systems: Processing of medical data from CT/MRI scan to 3D model in MIMICS, 3D-Doctor, Velocity^{2}Pro, VoXim, SurgiGuide, SimPlant Software, MIMICS software modules, Importing data, thresholding, segmentation, Editing, region growing, volume reduction, 3D Visualization, surgical simulation, Meshing, Measurement tools, Smoothing tools, STL conversion, Morphological operations, Labelling, volume, RP file generation, Practice on Medical Modelling.

Biomaterials: Introduction to Biomaterials, Metallic Biomaterials, Ceramic Biomaterials, Polymeric Biomaterials, Composite Biomaterials, Biodegradable Polymeric Biomaterials, Tissue-derived Biomaterials.

Virtual and Diagnostic Models in Medicine: Surgical applications of virtual models in Cranio-maxillofacial biomodelling, Oral and Maxillofacial surgery, customized cranio-maxillofacial prosthetics, Biomodel-guided stereotaxy, Vascular biomodelling, Skull-base tumour surgery, Spinal surgery and Orthopaedic biomodelling.

Planning and Simulation of Complex Surgeries: Cranioplasty of large cranial defect, Congential malformation of facial bones, Cosmetic facial reconstruction, Separation of conjoined twins, Tumor in the jaw, Cancerous brain, Dental precision planning and Spinal instrumentation.

Design and Fabrication of Customized Implants and Prosthesis: Cranium implants, Hip implants, Knee implants, Intervertebral spacers, Buccopharyngeal stent, Tracheobronchial stents, Obturator prosthesis and Tissue engineering scaffolds. A discussion on few benchmark case studies.

Design and Production of Medical Devices: Biopsy needle housing, Drug delivery devices, Masks for burnt victims, Functional prototypes help prove design value, Design and fabrication of non-implantable devices, Tools, Guides, Templates, etc., Design and Fabrication of Medical Support Devices like Arm, Knee Braces, etc., Design and Fabrication of Health Monitoring Devices.

Additive Manufacturing Related Technology in Sports, Rehabilitation, Device for Elderly, Forensic Science and Anthropology, Tissue Engineering and Organ Printing.

Learning Resources:

Text Books:

1. Medical Modelling: The Application of Advanced Design and Rapid Prototyping Techniques in Medicine, Richard Bibb, Dominic Eggbeer and Abby Paterson, Woodhead publishing, 2017.
2. Advanced Manufacturing Technology for Medical Applications, Ian Gibson, John Wiley, 2005.

Reference Books:

1. Bio-Printing: Principles and Applications, Chua Chee Kai and Yeong Wai Yee, World Scientific Publishing, 2015.
2. Bio-materials and Prototyping Applications in Medicine, Paulo Bartolo and BopayaBidanda, Springer, 2008.
3. 3D Printing in Medicine, Deepak M Kalaskar, Woodhead publishing, 2017.
4. 3D Printing in Medicine: A Practical Guide for Medical Professionals, Frak J. Rybicki, Gerald T. Grant, Springer, 2017.
5. The Biomedical Engineering Hand Book, Joseph D. Bronzino, 3rd Edition, CRC Press, 2006.

Online Resources:

1. https://medicalfuturist.com/3d-printing-in-medicine-and-healthcare/

2. https://zortrax.com/applications/medicine/
3. https://amfg.ai/2019/08/30/3d-printing-in-healthcare-where-are-we-in-2019/
4. https://tractus3d.com/used-by/branches/healthcare/

ME5762	POWDERS FOR ADDITIVE MANUFACTURING	3-0-0: 3

Pre-Requisites: -NIL-

Course Outcomes:

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

CO1	Propose manufacturing techniques to produce powders for additive manufacturing applications
CO2	Characterize powders developed from different manufacturing processes
CO3	Identify appropriate compaction techniques to densify powder preforms
CO4	Analyse the sintering mechanism of powder compacts
CO5	Propose methods to develop mechanical components through additive manufacturing techniques

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			3	2		
CO2	2		2	3		
CO3	2		3	3	2	
CO4	2		3	2	2	2
CO5	2		3	3		2

Detailed Syllabus

General Concepts: Introduction and History of Powder Metallurgy and powders for additive manufacturing.

Powder Production Techniques: Different Mechanical and Chemical methods, Atomisation of Powder, other emerging processes, Performance Evaluation of different Processes, processing of metal powders, production and qualification of polymer powders.

Characterization Techniques: Particle Size & Shape Distribution, Electron Microscopy of Powder, Interparticle Friction, Compressionability, Powder Structure, Chemical Characterization

Microstructure Control in Powder: Importance of Microstructure Study, Microstructures of Powder by Different techniques

Powder Shaping: Particle Packing Modifications, Lubricants & Binders, Powder Compaction & Process Variables, Pressure & Density Distribution during Compaction, Isostatic Pressing, Injection Molding, Powder Extrusion, Slip Casting, Tape Casting, Analysis of Defects of Powder Compact.

Metal powders in additive manufacturing: powders for direct energy deposition, powder for powder bed fusion process, requirements for powders used in additive manufacturing, handling of metal powders.

Sintering: Theory of Sintering, Sintering of Single & Mixed Phase Powder, Liquid Phase Sintering, Sintering Variables, Modern Sintering Techniques, Physical & Mechanical Properties Evaluation, Structure-Property Correlation Study, Modern Sintering techniques, Defects Analysis of Sintered Components.

Application of Powder metallurgy parts, Additive manufactured parts and A few case studies.

Learning Resources:

Text Books:

1. Powder Metallurgy Technology, G. S Upadhyaya, Cambridge International Science Publishing, 2002. 2nd Edition.
2. Powder Metallurgy Science, Technology and Materials, Anish Upadhyaya, Gopal Shankar Upadhyaya, Taylor & Francis Group, 2018.
3. Powder Metallurgy- Science, Technology and Applications, P. C. Angelo and R. Subramanian, PHI, New Delhi, 2008.

Reference Books:

1. Introduction to Powder Metallurgy, J. S. Hirschhorn, American Powder Metallurgy Institute, Princeton, NJ, 1976.
2. ASM Hand Book, vol. 7: Powder Metallurgy, ASM International
3. Advances in Powder Metallurgy: Properties, Processing and Applications, Isaac Chang, Yuyuan Zhao, Woodhead Publishing Series in Metals and Surface Engineering, Elsevier, 2013.
4. Powder Metallurgy, S. A. Tsukerman, Pergamon publishing, 1965, 1st Edition.

Online Resources:

3. https://www.epma.com/
4. https://www.pmai.in/
5. https://www.hoganas.com/en/powder-technologies/additive-manufacturing-metal-powders/
6. https://www.metalpowder.sandvik/en/products/applications/additive-manufacturing/
7. https://nptel.ac.in/courses/113/106/113106098/

ME 5763	RE- ENGINEERING	3-0-0: 3

Pre-requisites: -NIL-

Course Outcomes:

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

CO1	Identify the steps involved in re-engineering of a given component.
CO2	Design an existing component with suitable modifications as per customer's requirements.
CO3	Select and configure a suitable re-engineering system for inspection and manufacturing.
CO4	Apply the re-engineering techniques in aerospace, automobile and medical sectors.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1				3		
CO2	3	2	2	3	3	
CO3	3				3	
CO4	3		2	3	3	

Detailed Syllabus:

Introduction to reverse engineering, Re-Engineering–The Generic Process

Geometric Modelling using Point Cloud Data: Point Cloud acquisition, Surface Modelling from a point clouds, Meshed or Faceted Models, Planar Contour Models, Points to Contour Models, Surface Models, Segmentation and Surface Fitting for Prismatic objects and Free Form Shapes.

Methodologies and Techniques for Re-Engineering: The Potential for Automation with 3-D Laser Scanners, What Is Not Re-Engineering, What is Computer-aided (Forward) Engineering, What Is Computer-aided Reverse Engineering, Computer Vision and Re-Engineering.

Re-Engineering–Hardware and Software: Contact Methods Noncontact Methods, Destructive Method.

Selecting a Re-Engineering System: The Selection Process, Some Additional Complexities, Point Capture Devices, Triangulation Approaches, "Time-of-flight" or Ranging Systems, Structured-light and Stereoscopic Imaging Systems, issues with Light-based Approaches, Tracking Systems, Internal Measurement Systems, X-ray Tomography, Destructive Systems, Some Comments on Accuracy, Positioning the Probe, Post processing the Captured Data, Handling Data Points, Curve and Surface Creation, Inspection Applications, Manufacturing Approaches.

Integration between Re-Engineering and Additive Manufacturing: Modeling Cloud Data in Re-Engineering, Data Processing for Rapid Prototyping, Integration of RE and RP for Layer-based Model Generation, Adaptive Slicing Approach for Cloud Data Modeling, Planar

Polygon Curve Construction for a Layer, Determination of Adaptive Layer Thickness.

Re-Engineering in Automotive, Aerospace, Medical sectors: Legal Aspects of Re-Engineering: Copyright Law, Re-Engineering, Recent Case Law, Barriers to Adopting Re-Engineering. A discussion on a few benchmark case studies.

Learning Resources:

Text Books:

1. Product Design: Techniques in Reverse Engineering and New Product Development, K. Otto and K. Wood, Prentice Hall, 2001.
2. Reverse Engineering: An Industrial Perspective, Raja and Fernandes, Springer-Verlag 2008.

Reference Books:

1. Computer Aided Engineering Design, Anupam Saxena, Birendra Sahay, Springer, 2005.
2. Engineering Design and Rapid Prototyping, Ali K. Kamrani and EmadAbouel Nasr, Springer, 2010.
3. Advanced CAD Modeling Explicit, Parametric, Free-Form CAD and Re-engineering, Nikola Vukašinović and, JožeDuhovnik, Springer, 2019.

Online Resources:

1. https://www.polyga.com/reverse-engineering-101-scan-to-cad/
2. https://www.bft international.com/en/artikel/bft_Reverse_engineering_techniques_From_3D_scanning_to_the_CAD_file_in_the_3357131.html
3. https://physicaldigital.com/what-is-reverse-engineering/
4. https://all3dp.com/2/reverse-engineering-software-reverse-engineering-tools/

ME 5764	METALLURGY OF ADDITIVE MANUFACTURING	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

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

CO1	Understand physical metallurgy of strengthening mechanism of metals.
CO2	Understand the solidification of metals and segregation mechanism
CO3	Understand various cracking and fracture during solidification
CO4	Analysethe microstructure evolution, solidification and issues during 3D printing of steel
CO5	Analyse the microstructure evolution, solidification and issues during 3D printing of nickel and titanium
CO6	Apply post processing strategy to improve mechanical properties of 3D printed metals

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		3	3	2	
CO2	2		3	3	2	
CO3	3		3	3	2	
CO4	3		3	3	2	
CO5	3		3	3	2	
C06	3		3	3	2	

Detailed Syllabus

Introduction to Physical Metallurgy: Mechanical properties of metals, Dislocations and strengthening mechanisms, Failure, Grain structure and recrystallization, Phase Diagrams, Phase transformations: Development of microstructure and alteration of mechanical properties, strengthening mechanisms

Solidification of Metals: Solidification of metals, interface stability, microscopic aspects of solidification, solute redistribution: macroscopic and microscopic, segregation mechanism, recrystallization and grain growth, allotropic transformation, precipitation reactions

Cracking and fracture: Fracture toughness, Solidification cracking, reheat cracking, liquation cracking, cold cracking, strain-age, and ductility dip cracking

Metallurgy of Steel: Introduction of additive manufacturing of steel, Physical and mechanical metallurgy of austenitic and PH steels solidification mode in austenitic and PH steels, processing issues with 3D printing of steel, case study on metallurgical aspects using laser based process.

Metallurgy of Nickel based alloys: Nickel base alloy classification, physical and mechanical properties of precipitation based-strengthened Nickel based alloys, solidification and microstructure evolution, processing issues, case study on metallurgical aspects using arc based process.

Metallurgy of Titanium based alloys: Titanium base alloy classification, physical and mechanical properties of alpha beta titanium alloys, solidification and microstructure evolution, processing issues, case study on metallurgical aspects using electron beam based process.

Post Processing treatment for property improvement: Thermal post processing, hot isostatic pressing, recrystallization, stress relieving, solution treatment and aging

Learning Resources:

Text Books:

1. Metallurgy and mechanics of welding: processes and industrial applications. Blondeau, Régis, ed John Wiley & Sons, 2013.

Reference Books:

1. Welding Metallurgy and Weldability of Stainless Steels, by John C. Lippold, Damian J. Kotecki, pp. 376. ISBN 0-471-47379-0. Wiley-VCH, March 2005.2. ASM Hand book – Surface Engineering, ASM International, vol. 5, 994, 9th edition.
2. Welding metallurgy and weldability of nickel-base alloys. Lippold, J. C., Kiser, S. D., & DuPont, J. N., John Wiley & Sons, 2011.

Online Resources:

1. https://www.coursera.org/learn/additive-technologies-in-metallurgy--mechanical-engineering
2. https://onlinecourses.nptel.ac.in/noc19_mm19/preview

DETAILED SYLLABUS
LABORATORY COURSES
(I – YEAR, II – SEMESTER)

ME 5353	MANUFACTURING SIMULATION LABORATORY	0-1-2: 2

Pre-requisites: NIL

Course Outcomes:

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

CO1	Design and run simulation experiments using Discrete event simulation.
CO2	Model and study a given manufacturing scenario.
CO3	Analyze the behaviour of manufacturing system.
CO4	Evaluate and compare different manufacturing control policies

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3	3	3
CO2	3	2	3	3	3	3
CO3	3	2	3	3	3	3
CO4	2	2	3	3	3	3

List of Experiments:

1. Simulation of single line multi stage manufacturing system.
2. Simulation of multi line multi stage manufacturing and assembly system.
3. Simulation of manufacturing systems under variability conditions.
4. Study the effect of variability on performance of typical manufacturing system.
5. Simulation of CONWIP control system.
6. Simulation of KANBAN control system.

Learning Resources:

Text Books:

1. Discrete Event System Simulation. Jerry Banks. John S. Carson, II. Barry L. Nelson. David M. Nicol, Pearson, 2010, 5thEditon.

References:

1. https://www.flexsim.com/videos/flexsim-hc-2020-tutorial/
2. http://people.brunel.ac.uk/~mastjjb/jeb/info.html
3. https://informs-sim.org/wsc01papers/122.PDF.

ME 5344	CNC & AM LABORTORY	0-1-2: 2

Pre-requisites: NIL

Course Outcomes:

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

CO1	Develop manual part programs for 2D-complex profiles for Fanuc and Siemens Controller using CNC Simulator and Sinutrain Software.
CO2	Generate CNC program for turning and milling of component using Master CAM and EdgeCAM softwares.
CO3	Generate and verify CNC code using Virtual CNC software.
CO4	Machine complex profiles on CNC machine using autogenerated CNC code.
CO5	Generate and verify STL files and print 3Dparts by AM machines

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3	3	3
CO2	2	2	3	3	3	3
CO3			3	3	3	3
CO4	3	2	3	3	3	3

LISTOFEXPERIMENTS:

1. Simulation of turn components on CNC Simulator.
2. Turning of components on spinner.comlathe.
3. Turning of components on VDF lathe.
4. Milling simulation of 2Dprofiles on CNC Simulator.
5. Milling Simulation of Turbine blade on CNC Simulator.
6. Milling of 2Dprofiles on MaxMill CNC milling Machine.
7. Milling of 2D/ 3D profiles using Master Cam.
8. Milling of 2D/ 3D profiles using EdgeCam.
9. Generate and visualize CNC code using Virtual CNC Software.
10. Design and fabrication of components using MOJO3Dprinter.

Learning Resources:

Text Books:

1. NITWCNC LabManual,
2. Computer Numerical Control: Operation and Programming, John Stenerson and Kelly Curran, PHI, New Delhi, 2009.
3. Computer Aided Manufacturing, TCChang, RAWysk and HPWang, PHI,New Delhi,2009.

Reference Books:

1. Computer Numerical Control: Operation and Programming, John Stenerson and KellyCurran, PHI, 2009.
2. Computer Aided Manufacturing, TCChang, RAWysk and HPWang, PHI,New Delhi, 2009.

ME 5398	SEMINAR II	0-0-3: 1

Pre-requisites: NIL

Course Outcomes:

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

CO1	Identify and compare technical and practical issues related to the area of course specialization.
CO2	Outline annotated bibliography of research demonstrating scholarly skills.
CO3	Prepare a well-organized report employing elements of technical writing and critical thinking
CO4	Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2			3
CO2	3	2	2			3
CO3	3	3	2			3
CO4	3	3	2			3

Syllabus:

1. Identify the topic from scientific online resources
2. Conduct literature survey from the identified topic
3. Understand the identified topic and explore the contents critically

Task	Description	Weightage
I	Clarity on the topic	10
II	Literature survey	30
III	Content	30
IV	Presentation	20
V	Response to Questions	10
TOTAL		100

Task-CO mapping:

Task/CO	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X
V				X

Learning Resources:

References:

1. https://www.sciencedirect.com/
2. https://scholar.google.com/

DETAILED SYLLABUS

(II – YEAR, I – SEMESTER)

ME6347	COMPREHENSIVE VIVA – VOCE	Credits :2

COMPREHENSIVE VIVA – VOCE OUTCOMES: At the end of the comprehensive viva-voce, the student shall be able to:

CO1	Comprehend the knowledge gained in the course work
CO2	Identify principles of working of Computer Integrated manufacturing systems and controls
CO3	Demonstrate the ability in problem solving and to communicate effectively.

CO-PO MAPPING:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		3	2		3
CO2	3		3	3	2	3
CO3	3		3	3	3	3

ME6349	Dissertation Part – A	Credits: 12

DISSERTATION OUTCOMES: At the end of the part – A of dissertation, the student shall be able to:

CO1	Identify a topic in advanced areas of Computer Integrated manufacturing
CO2	Review literature to identify gaps and define objectives and scope of the work
CO3	Employ the ideas from literature and develop research methodology
CO4	Develop a model, experimental set-up and/or computational techniques necessary to meet the objectives.

M.Tech Dissertation Rubric Analysis:

Task	Description
I	Selection of Topic
II	Literature Survey
III	Defining the Objectives and Solution Methodology
IV	Performance of the Task
V	Dissertation Preparation
VI	Review (Presentation & Understanding)
VII	Viva-Voce
VIII	Publications /Possibility of publication

	ME 6349			
Task (% Weightage)	**CO1**	**CO2**	**CO3**	**CO4**
I (10)	X			
II (20)	X	X		
III (30)			X	
IV (40)				X

CO-PO MAPPING:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	1		3
CO2	3	2	3	1		3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3

DETAILED SYLLABUS

(II – YEAR, II – SEMESTER)

ME6399	Dissertation Part – B	20 Credits

DISSERTATION OUTCOMES: At the end of the part – B of dissertation, the student shall be able to:

CO1	Identify the materials and methods for carrying out experiments/develop a code
CO2	Execute the research methodology with a concern for society, environment and ethics
CO3	Analyse, discuss and justify the results/trends and draw valid conclusions
CO4	Prepare the report as per recommended format and present the work orally adhering to stipulated time
CO5	Explore the possibility to publish/present a paper in peer reviewed journals/conference without plagiarism

Task – CO Mapping:

	ME 6399				
Task (% Weightage)	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
IV (40)	X	X			
V (20)				X	
VI (10)			X		
VII (20)				X	
VIII (10)					X

CO-PO MAPPING:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2		3	3	2	3
CO2	2		3	3	2	3
CO3	3		3	3	2	3
CO4	3	3	3	3	3	3
CO5	3	3	3			3

NOTE: Refer to the following link for the guidelines to prepare dissertation report: https://www.nitw.ac.in/main/PGForms/NITW/