NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

M.TECH –Manufacturing Engineering

SCHEME OF INSTRUCTION AND SYLLABI

for M.Tech. Manufacturing Engineering Programme

(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 programmes - Thermal Engineering, Manufacturing Engineering, Computer Integrated Manufacturing, Machine Design, Automobile Engineering, Materials and Systems Engineering Design, Additive Manufacturing – one P.G Diploma in Additive Manufacturing and Ph.D programmes. 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, CMTI, CPRI 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 programmes 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:

Programme	Title of the Programme
B.Tech.	Mechanical Engineering
M.Tech.	Thermal Engineering
	Automobile Engineering
	Manufacturing Engineering
	Machine Design
	Computer Integrated Manufacturing
	Materials And Systems Engineering Design
	Additive Manufacturing
P.G. 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. – Manufacturing Engineering

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	Analyze, design and evaluate manufacturing processes using the knowledge of mathematics, science, engineering and IT tools.
PEO2	Solve real life manufacturing engineering problems using technological advancements for societal development.
PEO3	Apply management principles to execute projects of inter-disciplinary nature adhering to professional ethics.
PEO4	Engage in lifelong learning to adapt to the changing needs for professional advancement.

Programme 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	3	3	2
Develop linkages with world-class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.	3	3	3	2

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

M.Tech. – Manufacturing Engineering

Programme Outcomes

Programme Outcomes 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 behavior the students acquire through the programme. The Programme Outcomes (PO) 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 manufacturing engineering at a level higher than the Bachelor's programme.
PO4	Apply engineering knowledge, techniques and modern tools to analyze problems in manufacturing engineering.
PO5	Develop and validate models to solve complex problems in manufacturing systems using modern engineering and IT tools.
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. (Manufacturing Engineering)

I – Year, I – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	ME5201	Metal Cutting – Theory and Practice	3	0	0	3	PCC
2	ME5202	Design and Analysis of Machine Tools	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	ME5205	Manufacturing Engineering Laboratory	0	1	2	2	PCC
8	ME5206	CAE Laboratory	0	1	2	2	PCC
9	ME5248	Seminar – I	0	0	3	1	SEM
		Total	**18**	**2**	**7**	**23**	

I – Year, II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	ME5251	Advanced Manufacturing Technology	3	0	0	3	PCC
2	ME5252	Precision Engineering	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	ME5253	Precision Engineering Laboratory	0	1	2	2	PCC
8	ME5254	AM and MCT Laboratory	0	1	2	2	PCC
9	ME5298	Seminar – II	0	0	3	1	SEM
		Total	**18**	**2**	**7**	**23**	

II – Year, I – Semester

S. No.	Course Code	Course Title	Credits	Cat. Code
1	ME6247	Comprehensive Viva-voce	2	CVV
2	ME6249	Dissertation Part-A	12	DW
		Total	**14**	

II – Year, II – Semester

S. No.	Course Code	Course Title	Credits	Cat. Code
1	ME6299	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
Programme Specific Elective Courses					
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. Computer Integrated Manufacturing					
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. MSED					
1	ME5611	Surface Engineering	3-0-0	3	PEC
2	ME5613	Mechanics of Metal Forming	3-0-0	3	PEC
Elective Courses from M.Tech. Additive Manufacturing					
1	ME5711	Integrated Product Design and Development	3-0-0	3	PEC
2	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
Elective Courses from M.Tech Machine Design					PEC
1	ME5415	Mathematical Methods in Engineering	3-0-0	3	PEC

I Year, II Semester

S. No.	Course Code	Course Title	L-T-P	Credits	Cat. Code
Programme Specific Elective Courses					
1	ME5261	High Speed Machining	3-0-0	3	PEC
2	ME5262	Product Design for Manufacturing and Assembly	3-0-0	3	PEC
3	ME5263	Tool Design	3-0-0	3	PEC
4	ME5264	Geometric Dimensioning and Tolerancing	3-0-0	3	PEC
5	ME5265	Mechatronics and Robotics	3-0-0	3	PEC
Elective Courses from M.Tech. Computer Integrated Manufacturing					
1	ME5361	Supply Chain Management	3:0:0	3	PEC
2	ME5362	Mod. & Simulation of Manufacturing Systems	3-0-0	3	PEC
3	ME5363	Flexible 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 4.0 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. MSED					
1	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 of Additive Manufacturing	3-0-0	3	PEC
Elective Courses from M.Tech Thermal Engineering					
1	ME5162	Advanced Computational Fluid Dynamics	3-0-0	3	PEC
2	ME5170	Essentials of Entrepreneurship	3-0-0	3	PEC
3	ME5113	Renewable Sources of Energy	3-0-0	3	PEC
4	ME5114	Energy Systems and Management	3-0-0	3	PEC
Elective Courses from M.Tech Machine Design					
1	ME5466	Tribology In Design	3-0-0	3	PEC
2	ME5467	Advanced Composite Technologies	3-0-0	3	PEC
3	ME5468	Robotics	3-0-0	3	PEC
4	ME5469	Optimization Methods for Engineering Design	3-0-0	3	PEC
5	ME5403	Mechanical Vibrations	3-0-0	3	PEC
6	ME5452	Finite Element Analysis in Design	3-0-0	3	PEC

DETAILED CORE COURSES SYLLABUS

M.Tech. –Manufacturing Engineering

ME 5201	METAL CUTTING - THEORY AND PRACTICE	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Develop interrelations among ASA, ORS and NRS systems of tool geometry.
CO2	Analyze cutting forces, temperature, power and specific energy along the shear and rake planes.
CO3	Evaluate shear angle relationships and coefficient of friction in natural and controlled contact cutting.
CO4	Select cutting fluids, cutting tool materials and tool geometry for improving machinability and tool life.
CO5	Select modern machining processes for machining a given material and required part accuracies.

Course Articulation Matrix:

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

Syllabus:

Introduction: Overview of the course, Examination and Evaluation patterns, Classification of Manufacturing Processes, History of Machining, Scope and Significance of Machining

Geometry of Cutting Tools: Geometry of single-point cutting tool: Tool-in hand system, ASA system, Significance of various angles of single point cutting tools, Orthogonal Rake System (ORS), Conversions between ASA and ORS systems – Graphical and Analytical Methods, Normal Rake System (NRS) & relation with ORS

Mechanics of Machining Processes: Orthogonal and Oblique cutting, Mechanics of Chip formation: Types of chips, chip-breakers, Chip reduction coefficient, shear angle, shear strain, Built-Up-Edge and its effect in metal cutting, Merchant's analysis of metal cutting process - Various forces, power and specific energy in cutting, Problems on Tool Geometry and Mechanics of Machining, Theories of Metal Cutting: Ernst & Merchant, theory, Modified Merchant's theory, Lee & Shaffer Theory, Chip-tool Natural Contact Length – Hahn's Analysis, Stress distribution at Chip-Tool Interface – Zorev's Analysis, Machining with controlled contact cutting, Chip breakers.

Thermal aspects in machining: Sources of heat generation, Effects of temperature, Determination of cutting temperature using analytical methods, Determination of cutting temperature using experimental methods, Methods of Controlling Cutting Temperature,

Tool wear, Tool life, Machinability and Machining Economics: Wear Mechanisms, Types of tool wear, Tool Life and Machinability, A brief treatment for single pass turning operations, Problems on Economics of Machining

Cutting Tool Materials: Desirable Properties of tool materials, Characteristics of Cutting Tool Materials, indexable inserts, coated tools

Cutting Fluids: Functions, characteristics and types, selection of cutting fluids

Mechanics of Multipoint Machining processes: Drill geometry & Mechanics of drilling process, Geometry of milling cutters and Mechanics of milling process, Mechanics of grinding (plunge grinding and surface grinding), Grinding wheel wear

Oblique Cutting: Inclination Angle, Chip Flow angle, Mechanics of oblique cutting

Material Removal Mechanism of Advanced Machining Processes:
Mechanical energy based machining processes: Abrasive jet machining, Ultrasonic machining, Water jet machining, Abrasive water jet machining.
Thermo-electric energy based machining processes: Laser beam machining, Electron beam machining, Electric discharge machining, Plasma arc machining.
Chemical energy based machining processes: Chemical machining, Electro-Chemical machining, Bio-Chemical machining.

Learning Resources:

Text Books:

1. Metal cutting-Principles and Practices, M. C. Shaw, Cambridge University press. 2005
2. Manufacturing Technology–Metal Cutting and Machine Tools, P.N.Rao, TMH, New Delhi, 2013.
3. Metal Cutting: Theory and Practice, A.Bhattacharya, New Central Book Agency, Kolkata, 2007
4. Advanced Machining Processes, V. K. Jain, Allied Publisher, Mumbai, 2009
5. Modern Machining Processes, P.C.Pandey and H.S.Shah, TMH, 1981

Reference Books:

1. Fundamentals of Machining and Machine Tools,Winston A. Knight and Geoffrey Boothroyd Taylor and Francis Group, 2005.

Online resources:

https://nptel.ac.in/courses/112/105/112105233/

ME 5202	DESIGN AND ANALYSIS OF MACHINE TOOLS	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Design and analyze kinematic motions in a machine tool.
CO2	Design and analyze speed and feed gear boxes
CO3	Design guide ways, spindles and lead screws in machine tools
CO4	Analyze machine tool vibration and chatter
CO5	Select alignment tests to be performed on a machine tool for quality assurance

Course Articulation Matrix:

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

Syllabus:

Introduction to Machine Tool Drives and Mechanisms: Introduction to the course, Working and Auxiliary Motions in Machine Tools, Kinematics of Machine Tools, Motion Transmission.

Regulation of Speed and Feed Rates: Aim of Speed and Feed Regulation, Stepped Regulation of Speeds, Multiple Speed Motors, Ray Diagrams and Design Considerations, Design of Speed Gear Boxes, Feed Drives, Feed Box Design.

Design of Machine Tool Structures: Functions of Machine Tool Structures and their Requirements, Design for Strength Design for Rigidity, Materials for Machine Tool Structures, Machine Tool , Constructional Features, Beds and Housings, Columns and Tables, Saddles and Carriages.

Design of Guideways and Power Screws: Functions and Types of Guide ways, Design of Guide ways, Design of Aerostatic, Slide ways, Design of Anti-Friction Guide ways, Combination Guide ways, Design of Power Screws.

Design of Spindles and Spindle Supports: Functions of Spindles and Requirements, Effect of Machine Tool Compliance on machining Accuracy, Design of Spindles, Antifriction Bearings.

Dynamics of Machine Tools: Machine Tool Elastic System, Static and Dynamic Stiffness, Stability Analysis, Machine Tool Chatter, Damping Characteristics, Damping Methods.

Control Systems in Machine Tools: Machine tool control systems, Control Systems for Speed and Feed Changing, Adaptive Control Systems.

Testing of CNC Machine Tools: Alignment tests, Estimation of positional and geometrical accuracies.

Learning Resources:

Text Books:

1. Machine Tool Design and Numerical Control, N.K. Mehta, TMH, New Delhi, 2010
2. Principles of Machine Tools, G.C. Sen and A. Bhattacharya, New Central Book Agency, 2009.

Reference Books:

1. Design of Machine Tools, D. K Pal, S. K. Basu, 5th Edition. Oxford IBH, 2008.

Online resources:

1. https://onlinecourses.nptel.ac.in/noc21_me90/preview
2. https://www.wisc-online.com/learn/technical/machine-tool

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, Designation 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, guide ways etc.

Learning Resources:

Text Books:

1. Computer Control of Manufacturing Systems, YoramKoren, 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 and Programming , John Stenerson and Kelly Curran, PHI,NewDelhi, 2009
3. Computer Aided Manufacturing, Tien-Chien Chang, Richard AWysk and Hsu-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, BrentStucker, 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.

Course Articulation Matrix:

	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. 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.

DETAILED SYLLABUS
ELECTIVE COURSES
(I – YEAR, I – SEMESTER)

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 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

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, Hot-Isostatic 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 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:

1. Sheet metal forming processes Constitutive modelling and numerical simulation, D. Banabic, Springer-Verlag Berlin Heidelberg, 2010
2. Mechanics of sheet metal forming, Butterworth-Heinemann, Z. Marciniak, J. L. Duncan, S. J. Hu, Elsevier, 2002
3. Fundamentals of metal forming, R. H. Wagoner, J. L. Chenot, John Wiley and Sons, 1997
4. 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.

ME 5711	INTEGRATED PRODUCT DESIGN ANDDEVELOPMENT	3-0-0: 3

Pre-requisites: -NIL-

Course Outcomes:

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

CO1	Apply product design strategies for the development of innovative products
CO2	Develop new product models by applying the concepts of product design theory and robust design.
CO3	Apply embodiment principles in product development process.
CO4	Develop products by considering the social, environmental and ethical concerns.

Course Articulation Matrix:

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

Detailed Syllabus:

Introduction: Product Development and Design Theories-History, Road map to Engineering Design Process-stages, Technology insertion, Organization for design and product development, Business strategies, Working in teams, Assignment of course project.

Problem definition: Need Identification, Kano diagram, Establishing Engineering Characteristics, Quality Function Deployment (QFD)-, Product Design Specification (PDS), information sources.

Concept Generation and improvement: Creative methods for design, Functional decomposition and synthesis, Morphological methods, Theory of Inventive Problem solving (TRIZ), Axiomatic Design (AD).

Embodiment Design: Product Architecture, Configuration and Parametric design Concepts, Ergonomics and Design for Environment, and detailed design, Course project reviews.

Ethical Issues and Team Management: Ethical issues considered during Engineering design process, Contracts-Breach and discharge, product liability, Precautions by designer to avoid product liability.

Learning Resources:

Text Books:

1. Engineering Design, George E Dieter, Publisher, McGraw Hill, 2012, 4th edition

ReferenceBooks:

1. Kevin N. Otto, Kristin L. Wood, “Product Design”, Pearson Education, 2004.
2. W. Ernest Eder, S. Hosendl., “Design Engineering”, CRC Press, 2008.

Online Resources:

1. https://nptel.ac.in/courses/107/103/107103082/

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

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	Understand the stepwise procedure to completely solve a fluid dynamics problem using computational methods.
CO2	Derive the governing equations and understand the behavior of the equations.
CO3	Analyze the consistency, stability and convergence of various discretisation schemes for parabolic, elliptic and hyperbolic partial differential equations.
CO4	Analyze variations of SIMPLE schemes for incompressible flows and Variations of Flux Splitting algorithms for compressible flows.
CO5	Analyze various methods of grid generation techniques and application of finite difference and finite volume methods to various thermal problems.

Course Articulation Matrix:

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

Syllabus:

Introduction: History and Philosophy of computational fluid dynamics, CFD as a design and research tool, Applications of CFD in engineering, Programming fundamentals, MATLAB programming, Numerical Methods.

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

Mathematical behavior of partial differential equations: Classification of quasi-linear partial differential equations, Methods of determining the classification, General behavior of Hyperbolic, Parabolic and Elliptic equations.

Basic aspects of discretization: Introduction to finite differences, Finite difference equations using Taylor series expansion and polynomials, Explicit and implicit approaches, Uniform and unequally spaced grid points.

Grids with appropriate transformation: General transformation of the equations, Metrics and Jacobians, The transformed governing equations of the CFD, Boundary fitted coordinate systems, Algebraic and elliptic grid generation techniques, Adaptive grids.

Parabolic partial differential equations: Finite difference formulations, Explicit methods - FTCS, Richardson and DuFort-Frankel methods, Implicit methods - Lasonen, Crank-Nicolson

and Beta formulation methods, Approximate factorization, Fractional step methods, Consistency analysis, Linearization.

Stability analysis: Discrete Perturbation Stability analysis, von Neumann Stability analysis, Error analysis, Modified equations, Artificial dissipation and dispersion.

Elliptic equations: Finite difference formulation, solution algorithms: Jacobi-iteration method, Gauss-Siedel iteration method, point- and line-successive over-relaxation methods, alternative direction implicit methods.

Hyperbolic equations: Explicit and implicit finite difference formulations, splitting methods, multi-step methods, applications to linear and nonlinear problems, linear damping, flux corrected transport, monotone and total variation diminishing schemes, TVD formulations, entropy condition, first-order and second-order TVD schemes.

Scalar representation of Navier-Stokes equations: Equations of fluid motion, numerical algorithms: FTCS explicit, FTBS explicit, Dufort-Frankel explicit, McCormack explicit and implicit, BTCS and BTBCS implicit algorithms, SIMPLE algorithm, applications

Grid generation: Algebraic Grid Generation, Elliptic Grid Generation, Hyperbolic Grid Generation, Parabolic Grid Generation.

Finite volume method for unstructured grids: Advantages, Cell Centered and Nodal point Approaches, Solution of Generic Equation with tetrahedral Elements, 2-D Heat conduction with Triangular Elements.

Learning Resources:

Text Books:

- Computational Fluid Dynamics: the Basics with Applications, Anderson, J.D. (Jr), McGraw-Hill Book Company, 2017, Indian Edition.
- Computational Fluid Dynamics, Vol. I, II and III, Hoffman, K.A., and Chiang, S.T., Engineering Education System, Kansas, USA, 2000, 4th edition.
- Numerical Heat Transfer and Fluid Flow, Suhas V Patankar, CRC Press, 2018, Special Indian Edition.

Reference Books:

- Computational Fluid Dynamics, Chung, T.J., Cambridge University Press, 2014, 2nd Edition.
- Computational Fluid Mechanics and Heat Transfer, Anderson, D.A., Tannehill, J.C., and Pletcher, R.H., CRC Press, 2020, 4th Edition.

Online Resources:

Introduction to CFD by Prof. M. Ramakrishna (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/101/106/101106045/)

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

Prerequisites: NIL

Course Outcomes:

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 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.

Topics in Numerical Analysis: Interpolation, Regression, Numerical Integration, Numerical Solution of ODE's as IVP 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 , Pearson Education, 2006.
3. Scientific Computing, M. T. Heath, McGraw-Hill Education, 2001.
4. Applied Numerical Methods with Matlab, Steven Chapra, McGraw-Hill Education, 2011.

ELECTIVE COURSES DETAILED SYLLABUS OFFERED

TO OTHER SPECIALIZATIONS

(I – YEAR, I – SEMESTER)

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/

DETAILED SYLLABUS

LABORATORY COURSES

(I – YEAR, I – SEMESTER)

ME5205	MANUFACTURING ENGINEERING LABORATORY	0-1-2: 2

Pre-Requisites: NIL

Course Outcomes:

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

CO1	Prepare a single point cutting tool as per the ASA and NRS and estimate its tool life.
CO2	Evaluate the effect of process parameters on cutting forces and temperature in machining.
CO3	Evaluate the effect of process parameters on MRR and Surface finish in EDM and WEDM.
CO4	Simulate and machining of complex profiles on a CNC turning and milling machines using manual and auto generated CNC code.
CO5	Evaluate the geometrical accuracies of machined components using CMM.

Course Articulation Matrix:

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

Syllabus

List of Experiments:

1. Preparation of a single point cutting tool with a given tool geometry.
2. Estimation of chip reduction coefficient and shear angle in orthogonal cutting.
3. Evaluation of the effect of process parameters on cutting forces, surface finish and averagecutting temperature in turning process.
4. Evaluation of the effect of process parameters on cutting forces and surface finish in laser assisted turning process.
5. Evaluation of the effect of process parameters on cutting forces in milling process.
6. Estimation of tool life of a single point turning tool.
7. Evaluation of the effect of process parameters on MRR and Surface finish in EDM
8. Evaluation of effect of process parameters on MRR in WEDM
9. Evaluation of dimensional and geometrical accuracies of a given component on CMM.
10. Manual Part programming for Fanuc and Siemens Controller using CNC Simulator and sinutrain.
11. CNC programming and simulation using EdgeCAM, Sinutrain and MasterCAM
12. Writing part programs to machine components on CNC machines

Learning Resources:

Text Books:

1. Metal cutting-Principles and Practices, M. C. Shaw, Cambridge University press. 2005
2. Manufacturing Technology–Metal Cutting and Machine Tools, Rao PN, TMH, 2013.

3. Computer Numerical Control: Operation and Programming , John Stenerson and Kelly Curran, PHI, New Delhi, 2009.

ME 5206	COMPUTER AIDED ENGINEERING (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:

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

ME 5248	SEMINAR – I	0-0-2: 1

Pre-requisites: -NIL-

Seminar Outcomes:

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

CO1	Identify and compare technical and practical issues related to Additive Manufacturing.
CO2	Outline annotated bibliography of research demonstrating scholarly skills.
CO3	Prepare a well-organized report employing elements of critical thinking and technical writing.
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

Evaluation Scheme:

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

CORE COURSES

(I – YEAR, II – SEMESTER)

ME5251	ADVANCED MANUFACTURING TECHNOLOGY	3-0-0: 3

Pre-Requisites: Nil

Course Outcomes:

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

CO1	Apply advanced casting methods including stir casting and centrifugal casting for making composite materials and its characterization
CO2	Apply the knowledge in welding of dissimilar materials and characterization by using friction stir welding, laser and hybrid welding process
CO3	Select the suitable material and process for fabricating a product using Additive Manufacturing process
CO4	Analyze the forming components using high energy rate forming process
CO5	Analyze the wire arc additive Manufacturing and friction stir additive manufacturing components

Course Articulation Matrix:

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

Syllabus:

Advances in welding: Classification of solid state and fusion welding processes, Friction stir welding: process, parameters, tool design, advantages, limitations and applications, preparation of composites by Friction stir processing and characterization, Laser beam welding process, Hybrid welding process; -Process parameters, applications, advantages and limitations. **Wire arc additive Manufacturing:** Process, parameters, advantages and limitations, **Sheet Lamination Processes:** Bonding Mechanisms, Materials, Laminated Object Manufacturing (LOM), Friction stir additive Manufacturing

Additive Manufacturing: Introduction to AM, AM evolution, Distinction between AM & CNC machining, Steps in AM, Classification of AM processes, Advantages of AM. **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.

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

Advances in casting: Introduction to advances in casting processes, Stir casting process: Process parameters in stir casting process, advantages, limitations and application, composite preparation, analysis of composite. Centrifugal casting: Process parameters, preparation of composites and characterization, Functional graded materials by centrifugal casting process, applications and limitations

Advances in forming: Introduction forming processes, advantages, limitations and applications, Vacuum forming, Explosive forming, and hydro forming, advantages and applications, High velocity forming and Mar forming, advantages and applications, Electromagnetic forming, advantages and applications.

Material characterization and design considerations: Optical microscopy, micro hardness, SEM and XRD analysis of cast and welded structures.

Learning Resources:

Text Books:

1. Welding processes and Technology, R.S.Parmar, Khanna Publishers, 2012
2. Friction Stir Welding and Processing, R. S. Mishra, ASM International, 2007.
3. Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Ian Gibson, David W Rosen, Brent Stucker., 2nd Edition, Springer, 2015.
4. Forming, ASM Handbook, volume No 14, ASM International,1998
5. Casting, ASM Handbook, volume No 15, ASM International,1998

Reference Books:

1. Modern Machining Technology, A Practical Guide, J Paulo Davim, 1st Edition, Woodhead Publishing in Mechanical Engineering, 2011.
2. Materials Characterization, ASM Handbook, volume No 10, ASM International,1998.
3. Rapid Prototyping: Laser-based and Other Technologies, Patri K. Venuvinod and Weiyin Ma, Springer, 2004.
4. 3D Printing and Additive Manufacturing: Principles & Applications, Chua Chee Kai, Leong Kah Fai, 4th Edition, World Scientific, 2015.

Online Resources:

1. https://www.twi-global.com/
2. https://nptel.ac.in/courses/112/107/112107078/
3. https://nptel.ac.in/noc/courses/noc19/SEM1/noc19-mm08/
4. https://nptel.ac.in/courses/112/104/112104265/

ME5252	PRECISION ENGINEERING	3-0-0: 3

Pre-Requisites: Nil

Course Outcomes:

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

CO1	Design and apply fits and tolerances for parts and assemblies according to ISO standards.
CO2	Apply selective assembly concept for quality and economic production.
CO3	Design and allocate tolerances using principles of dimensional chains for individual features of a part or assembly.
CO4	Evaluate the part and machine tool accuracies.

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, accuracy specification 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, Design of limit gauges.

Theory of dimensional chains: Definitions, concept of dimensional chain or tolerance stack. Dimensioning of stepped shaft and holes, machining of a keyway in a bush, assigning tolerances on the constituent dimensions.

Geometric Dimensioning and Tolerancing: Tolerance Zone Conversions-Surfaces, Features of Size, Datum - Datum Feature of Representation-Form Controls, Orientation Controls-Logical Approach to Tolerancing-datum systems, geometrical tolerances.

Errors during machining: Errors due to compliance of machine- fixture-tool-workpiece (MFTW), theory of location, location errors, errors due to geometric inaccuracy of machine tools, errors due to tool wear, errors due to thermal effect, errors due to clamping.

Surface Roughness and Microfinishing Process: Definitions, relation among various indices of surface roughness, influence of machining parameters on surface roughness, methods of obtaining high quality surfaces, lapping, honing, super finishing and burnishing processes.

Manufacturing methods of machine tool components and tolerance charting technique:

Manufacturing methods of spindles, gears and beds, operation sequence for typical shaft type of component, preparation of process drawings for different operations, tolerance worksheets and centrally analysis

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
3. Process Engineering for Manufacture, Eary and Johnson
4. Dimensional control in Precision Manufacturing, J.L.Gadjala, McGraw Hill Publishers.

Reference Books:

1. Precision Eengineering, Venkatesh, V.C. and Sudin, I., Tata McGraw Hill Co., NewDelhi, 2007.
2. Geometric Dimensioning and Tolerancing, James, D. and Meadow, S., Marcel Dekker Inc., 1995.

DETAILED SYLLABUS

ELECTIVE COURSES

(I – YEAR, II – SEMESTER)

ME 5261	HIGH SPEED MACHINING	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Distinguish between conventional machining and high speed machining.
CO2	Analyze the determinants of high speed machining and improve its performance.
CO3	Evaluate the requirements on machine tool technology to support High Speed Machining.
CO4	Select cutting tool materials for high speed machining.
CO5	Estimate the impact of dry and near dry machining on environment.

Course Articulation Matrix:

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

Syllabus:

Introduction: Advanced Machining Processes, A new Era.

The Determinants of High-Speed Machining: Weight, Materials, Machine Tools, Simple Processes and Systems, Fast Machining, Response Time, and Throughput, Smart Machines, Tools, and Processes.

Characteristics of High-Speed Machining: Machining Parameters.

Machine-tool Technology: Manufacturing and Multi-task Machining Systems, High-Speed Machining, Support Technology.

Advanced Cutting Tools: Cutting-Tool Materials, Cutting-Tool Design, Tool Guidance and Stability, Chip Control, Burr Control, Stringent Finish Requirements, Cost and Quality, Intelligent Tooling.

Precision Tooling Interface: Connection and Interface, Tool Clamping, Balancing, Run-out.

Dry and Near-dry Machining: Environmental Impact, Dry Machining, Near-dry Machining, and Reducing Coolant Use.

Practical Applications: Precision Hard Machining, Machining Compacted Graphite Iron, Precision Roughing, Advanced Milling Operations, Machining with Multi-cut Tools.

Learning Resources:

Text Books:

1. High Speed Machining, Bert P. Erdel, SME Publications, Michigan, 2003
2. Hard Milling and High Speed Machining,Dale Mickelson, Industrial Press Inc, United States, 2007.

Reference Books:

1. Handbook of High-Speed Machining Technology, Robert I. King, springer nature, 2020.

Online resources:

http://nptel.tint.edu.in/mechanical.html

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, and 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 5263	TOOL DESIGN	3-0-0: 3

Pre-requisites: NIL

Course Outcomes:

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

CO1	Analyze the geometrical and dimensional details of a production drawing
CO2	Design locating and clamping systems for a given component
CO3	Design jigs and fixtures for conventional and NC machining
CO4	Select and design dies for press working operations
CO5	Design single point and multipoint cutting tools

CO-PO Mapping:

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

Syllabus:

Basic principles of tool design: Tool design – An overview, Introduction to Jigs and fixtures.

Work holding devices: Basic principle of six point location, Locating methods and devices, Principle of clamping and Types of clamps.

Design of jigs: Type of Drill bushes, Classification of drill jigs, Design of drill jigs.

Design of fixtures: Design of milling fixtures, Design of turning fixtures

Press tool design: Introduction to Die cutting operations, Introduction to press and classifications, Die set assembly with components, Introduction to Centre of pressure, Examples of center of pressure, Design of piercing die, Design of blanking die, Progressive, Compound and Combination dies.

Design of cutting tools: Introduction to cutting tools, Design of single point tool, Design of drill bit, Design of milling cutter

NC machines work holding devices: Tool design for NC machines- An introduction, Fixture design for NC Machine, Tool holding methods for NC Machine, ATC and APC for NC Machines, Tool presetting for NC Machine.

Learning Resources:

Text Books:

1. Tool Design, Donaldson.C, G.H.Lecain and V.C.Goold TMH, New Delhi, 2010

2. Fundamentals of Tool Design, Wilson.F.W, ASME, PHI, New Delhi, 2010.

Reference books:

1. Machine design data book, Lingaiah, Karnati, McGraw-Hill Education, 2003.

Online resources:

https://www.toolsdesign.com/

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, Devdas Shetty& 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
2. http:// mechatronics.me.wisc.edu

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
CO1	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 5374	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 ERPlean 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: NIL

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	

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.

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

References:

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

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 software.

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, UdhayanElongovan, 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 behavior 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 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 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, SudipMisra, Chandana Roy, Anandarup Mukherjee, CRC Press, 2020.
2. A Hands on Approach", Vijay Madisetti, ArshdeepBahga, 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 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

Detailed 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 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:

2. Product Design: Techniques in Reverse Engineering and New Product Development, K. Otto and K. Wood, Prentice Hall, 2001.
3. 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

ME5162	ADVANCED COMPUTATIONAL FLUID DYNAMICS	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:

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

Reference Books:

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

Online Resources:

- ★ Computational Fluid Dynamics using Finite Volume Method by Dr. Kameswararao Anupindi (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106294/)
- ★ Foundations of Computational Fluid Dynamics by Prof. S. Vengadesan (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106186/)

Computational Fluid Dynamics by Prof. Suman Chakraborty (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105045/)

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:

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

Reference Books:

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

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:

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

Reference Books:

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

Online Resources:

★ 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:

CO 1	Understand the fundamentals of energy management
CO 2	Apply the principles of thermal engineering and energy management to improve the performance of thermal systems.
CO 3	Analyze the methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems.
CO 4	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 Programmes, 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:

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

Reference Books:

- ❖ Energy Management Hand book, Doty, S. and Truner, W. C., Fairmont Press, 2009, 7th edition.

Online Resources:

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

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

Course Outcomes: NIL

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

CO1	Analyze properties of lubricant and select proper lubricant for a givenapplication.
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 tribodesign: Specific principles of tribodesign; 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 in lubricated contacts, 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 oflubricants, 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 pad bearing, 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., 3rd Ed., Elsevier, 2010.
2. Tribology in Machine Design, TA Stolarski, Butterworth-Heinemann, 2000.
3. Engineering Tribology, Williams JA, Oxford Univ. Press, 2001.
4. Introduction to bearings, Majumdar B.C, S. Chand & Co., Wheeler publishing, 1999.
5. Fluid film lubrication theory and design, Andras Z. Szeri, Cambridge Universitypress, 1998.
6. Basic lubrication theory, Cameron A, Ellis Horwood Ltd., 2002.
7. Tribology Hand Book, Neale MJ, CBS Publications, 2012.
8. Mechanical Vibrations, Venkatachalam R., PHI Publications, 2018

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

Course Outcomes: NIL

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 andin 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 fillers and 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, Volume 21, 2001.
4. Composite Materials, Science and Engineering, Krishan K. Chawla, Springer, 2001.
5. Process Modelling in Composites Manufacturing,Suresh G. Advani, E. Murat Sozer, 2nd Ed. CRC Press, 2009

ME 5468	ROBOTICS	3-0-0: 3

Course Outcomes: NIL

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

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	Programme robot to perform typical tasks including Pick and Place, Stacking andWelding
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 TransformationMatrix, 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., and Lee, C.S.G.,

McGraw-Hill Publishing company, New Delhi, 2003.

2. Engineering: An IntegratedApproach, Prentice Hall of India, Klafter, R.D., Chmielewski, T.A., and Negin. M, Robot New Delhi, 2002.
3. Introduction to Robotics Mechanics and Control, Craig, J.J., Addison Wesley, 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
   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

Course Outcomes: NIL

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 nonlinear 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, Optimization problems in Mechanical Engineering, Classification of methods for optimization

Single-variable Optimization: Optimal criteria, Derivative-free methods (bracketing, region elimination), Derivative based methods, root-finding methods.

Multiple-variable Optimization: Optimal criteria, Direct search methods (Box's,Simplex, Hooke-Jeeves, Conjugate methods), Gradient-based methods (Steepest Descent, Newton's, Marquardt's, DFP method). Formulation and Case studies.

Constrained Optimization: KKT conditions, Penalty method, Sensitivity analysis, Direct search methods for constrained optimization, quadratic programming, GRG method, Formulation and Case studies.
Specialized algorithms: Integer programming (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 Pareto optimality and Pareto optimal set, formulation of multi-objective optimization problem, NSGA.

Case studies 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, Academic Press, 2004
2. Optimization For Engineering Design: Algorithms and Examples, Kalyanmoy Deb, PHI, 2004.
3. Multi-Objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, Wiley,2001

ME 5403	MECHANICAL VIBRATIONS	3-0-0: 3

Course Outcomes: NIL

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

CO1	Analyze the causes and effects of vibrations in mechanical systems andidentify discrete and continuous systems.
CO2	Model the physical systems into schematic models and formulate thegoverning 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 nonlinear systems, Physical models, Schematic models and Mathematical models.

Single Degree of Freedom (SDF) systems: Formulation of equation of motion: Newton – Euler method, De Alembert'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 unbalances.

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

Design case studies: Design case studies dealing with Transmissibility of forces and motion, Vehicular suspension, Analysis of Vehicles as single degree of freedom systems -vibration transmitted due to unevenness of the roads, preliminary design of automobile suspension. Design of machine foundations and isolators.

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

Equilibrium method, Lagrangian method, Case studies on formulation of equations of motion, Free vibration response, Eigen values and Eigen vectors, Normal modes and mode superposition, Coordinate coupling, decoupling of equations of motion, Natural coordinates, Response to initial conditions, coupled pendulum, free vibration response case studies, 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, discrete vs 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, 2nd Ed. Tata Mc-Grawhill, 2007
2. Mechanical Vibrations. S Rao, 4th Ed., Pearson education, 2011
3. Theory of Vibration, W.T, Thompson, CBS Publishers
4. Vibration: Fundamentals and Practice, Clarence W. De Silva , CRC Press LLC,2000
5. Mechanical Vibrations, Venkatachalam R., PHI Publications, 2018

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

Course Outcomes: NIL

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

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 to mechanical engineering design problems.

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 weightedresidual method and through minimization of potential, displacement based formulation,Concept of discretization, Interpolation, Formulation of Finite element characteristicmatrices and vectors, Compatibility conditions, Assembly and boundary considerations.

Finite Element Analysis for One Dimensional Structural problems: Structuralproblems with one dimensional geometry. 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 and disadvantages. Formulation for Truss elements, Case studies involving hand calculations with an emphasis on Assembly, boundary conditions,contact conditions and multipoint constraints.

Beams and Frames: Review of bending of beams, higher order continuity (C^0 and C^1 Continuity), interpolation for beam elements and formulation of FE characteristics, Plane and

space frames and examples problems involving hand calculations. Algorithmic approach for developing computer codes involving 1-D elements.

Two dimensional Problems: Interpolation in two dimensions, natural coordinates, Isoparametric representation, Concept of Jacobian. Finite element formulation for plane stress plane strain and axi-symmetric problems; Triangular and Quadrilateral elements, higher order elements, sub-parametric, Isoparametric and superparametric elements. Formulation of plate bending elements using linear and higher order bending theories, Shell elements, General considerations in finite element analysis of design problems, Choosing an appropriate element and the solution strategies. Introduction to pre and post processing of the results and analysis.

Three Dimensional Problems: Finite element formulation for 3-D problems, mesh preparation, tetrahedral and hexahedral elements, case studies.

Dynamic Analysis: FE formulation in dynamic problems in structures using Lagrangian Method, Consistent and lumped mass models, Formulation of dynamic equations of motion, Modelling of structural damping and formulation of damping matrices, Model analysis, Mode superposition methods and reduction techniques.

FEM in Heat Transfer and Fluid Mechanics problems: Finite element solution for one dimensional heat conduction with convective boundaries. Formulation of element characteristics and simple numerical problems. Formulation for 2-D and 3-D heat conduction problems with convective boundaries. Introduction to thermo-elastic contact problems. Finite element applications in potential flows; Formulation based on Potential function and stream function. Case studies.

Algorithmic Approach for problem solving: Algorithmic approach for Finite element formulation of element characteristics, Assembly and incorporation of boundary conditions. Guidelines for code development. Introduction to commercial Finite Element software packages like ANSYS.

Learning Resources:

1. Finite element Method in Engineering, Singiresu S.Rao, 5ed, Elsevier, 2012.
2. Textbook of Finite Element Analysis, Seshu P, PHI. 2004
3. Finite Element Method in Engineering, Reddy, J.N., Tata McGraw Hill, 2017
4. The Finite Element Method 4 Vol set, Zeincowicz, 4th Edition, Elsevier 2007.

DETAILED SYLLABUS

LABORATORY COURSES

(I – YEAR, II – SEMESTER)

ME5253	PRECISION ENGINEERINGLABORATORY	0-0-3: 2

Pre-Requisites: NIL

Course Outcomes:

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

CO1	Estimate type of fit for a given assembly
CO2	Evaluate form errors like straightness, flatness, squareness, roundness and circularity
CO3	Evaluate dimensional and form accuracies of thread and gear profiles
CO4	Estimate the compliance of M-F-T-W system
CO5	Evaluate the effect of process parameters on surface finish during machining

Course Articulation Matrix:

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

List of Experiments

1. Estimation of type of fit in assemblies
2. Estimation of form errors like straightness, flatness and squareness on a machined component.
3. Evaluation of roundness and circularity on a machined component.
4. Production and evaluation of thread and gear profiles for their form and geometrical accuracies.
5. Evaluation of accuracy of machine tools for parallelism of guide ways, spindle runout, etc. in lathe, milling and drilling machines.
6. Estimation of compliance of machine- fixture-tool-workpiece using turned components
7. Evaluation of the effect of process parameters on surface roughness in turning, milling, drilling and grinding.

Text Books:

1. Lab instruction manual
2. Engineering Metrology, I.C. Gupta, DhanpatRai& Sons, 2003
3. Engineering Metrology, R. K. Jain, Khanna Publishers, 19/e, 2005.
4. Precision Engineering in Manufacturing, R.L.Murty, New Age International Publishers, 1996.

ME5254	ADDITIVE MANUFACTURING (AM) AND MATERIAL CHARACTERIZATION TESTING (MCT) LABORATORY	0-0-3: 2

Pre-Requisites: NIL

Course Outcomes:

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

CO1	Analyze the microstructure in cast, welded and formed components
CO2	Analyze the mechanical properties of various components
CO3	Interpret the defective analysis and correlate it to the mechanical properties
CO4	Analyze the Surface roughness of additive manufacturing components by image analysis
CO5	Analyze the additive manufacturing components (Metals and Polymers)

Course Articulation Matrix:

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

List of Experiments:

1. Characterization of cast, welded and formed components

i) Analyze the microstructure of welded and cast components

ii) Identification of phases in the microstructure

iii) Determination of Phase/volume fraction

iv) Grain size measurement using line intercept method / area method

v) EDX-analysis using SEM

2. Tensile behaviour of cast and welded and additive manufactured components

3. Fractography of cast and welded samples

4. Microhardness analysis of cast and welded components

5. NDT of cast and welded components

6. Demonstration of XRD Analysis

7. Fabrication and characterization of components using Additive manufacturing process (Metals and Polymers)

8. Analysis of additive manufactured components using 3D-microscope

Learning Resources:

Text Books:

1. Laboratory Instruction Manual.

Online Resources:

1. https://www.mri.psu.edu/materials-characterization-lab
2. https://uwaterloo.ca/applied-mathematics/current-undergraduates/continuum-and-fluid-mechanics-students/amath-361-students/material-characterization-laboratory
3. http://vlabs.iitkgp.ac.in/scm/
4. https://www.itwm.fraunhofer.de/en/departments/sms/lab-structural-fluid-mechanical-characterization-materials.html

ME 5298	SEMINAR – II	0-0-2: 1

Pre-requisites: -NIL-

Seminar Outcomes:

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

CO1	Identify and compare technical and practical issues related to Additive Manufacturing.
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

Evaluation Scheme:

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/

ELECTIVE COURSES DETAILED SYLLABUSOFFERED

TO OTHER SPECIALIZATIONS

(I – YEAR, II – SEMESTER)

DETAILED SYLLABUS

(II – YEAR, I – SEMESTER)

ME6247	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 additive 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

ME6249	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 additive 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 6249			
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)

ME6299	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 6299				
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/