CURRICULUM & SYLLABI

M.Tech. MANUFACTURING ENGINEERING

Effective from AY: 2024-25



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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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 societal needs.

Vision and Mission of the Department
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.

Program: M.Tech Manufacturing Engineering

Program Educational Objectives

PEO-1	Analyze, design and evaluate manufacturing processes using the knowledge of mathematics, science, engineering and IT tools.
PEO-2	Solve real life manufacturing engineering problems using technological advancements for societal development.
PEO-3	Apply management principles to execute projects of inter-disciplinary nature adhering to professional ethics
PEO-4	Engage in lifelong learning to adapt to the changing needs for professional advancement.

Program Articulation Matrix

PEO / Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4
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

Program: M.Tech Manufacturing Engineering

Program Outcomes

PO-1	Carryout independent research/investigation and development work to solve practical problems.
PO-2	Write and present a substantial technical report/document.
PO-3	Demonstrate a degree of mastery in manufacturing engineering at a level higher than the Bachelor's programme.
PO-4	Apply engineering knowledge, techniques and modern tools to analyze problems in manufacturing engineering.
PO-5	Develop and validate models to solve complex problems in manufacturing systems using modern engineering and IT tools.
PO-6	Engage in lifelong learning adhering to professional, ethical, legal, safety, environmental and societal aspects for career excellence.

CURRICULUM
M.Tech Manufacturing Engineering

1st Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME26001	Advanced Manufacturing Technology	3-0-0	3
2	ME26003	Advanced CAM & Intelligent Manufacturing Systems	3-0-0	3
3	ME26005	Machining Physics	3-0-0	3
4		Professional Elective – 1	3-0-0	3
5		Professional Elective – 2	3-0-0	3
6	ME26007	Advanced Manufacturing Technology Laboratory	0-1-2	2
7	ME26009	Manufacturing and Precision Engineering Laboratory	0-1-2	2
			Total Credits	**19**

2nd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME26002	Additive Manufacturing	3-0-0	3
2	ME26004	Mechatronics and Automation	3-0-0	3
3		Professional Elective – 3	3-0-0	3
4		Professional Elective – 4	3-0-0	3
5		Professional Elective – 5	3-0-0	3
6	ME26006	Mechatronics and automation Laboratory	0-1-2	2
7	ME26008	Modelling and analysis Laboratory	0-1-2	2
8	ME26096	Minor Project	0-0-0	2
			Total Credits	**21**

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME26089	Seminar and Technical Writing	0-0-0	2
2	ME26091	Summer Internship/Research Experience	0-0-0	2
3	ME26093	Comprehensive Viva-Voce	0-0-0	2
4	ME26097	Dissertation: Part-A	0-0-0	8
			Total Credits	**14**

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME26098	Dissertation: Part-B	0-0-0	12
			Total Credits	**12**

Professional Elective Courses:

Professional Elective – I & II		
S. No.	**Code**	**Course Title**
1.	ME26021	Precision Engineering
2.	ME26023	Mechanical Behavior and Characterization of Materials And NDT
3.	ME26025	Micro and Nano Manufacturing Processes
4.	ME26027	Mechanics of Metal Forming
5.	ME26031	Surface Engineering
6.	ME26033	Design and Analysis of Machine Tools
7.	ME26035	Finite Element Application in Materials Processing
8.	ME26037	Computational modeling of materials
9.	ME26039	Product Design and Assembly Automation
10.	ME26041	Operation Management
11.	ME26043	Microwave Materials Processing: Principles and Applications
12.	ME26045	Artificial Intelligence and Machine Learning in Materials Engineering
13.	ME16027	Energy Systems and Management
14.	ME46021	Computer Aided Geometric Design
15.	ME46027	Mathematical Methods in Engineering
16.	ME36029	Advanced CAD
17.	ME36021	3D printing Technologies
18.	ME36023	Data Science in Manufacturing
19.	ME36025	Augmented Reality and Virtual Reality
20.	ME36027	Design for Manufacturability
21.	ME36031	Materials, Energy Sources and Bonding Mechanisms
22.	ME36033	Circular Economy
23.	ME46033	Systems Thinking for Engineering Applications

Professional Elective – III, IV & V		
S. No.	**Code**	**Course Title**
1.	ME26022	Digital Twin in Manufacturing
2.	ME26026	Advanced Composite Materials and Processing
3.	ME26028	Design and Analysis of Experiments
4.	ME26030	Product Lifecycle Management
5.	ME26032	Rapid Tooling and Industrial Applications
6.	ME26034	Sustainable Manufacturing
7.	ME26036	Computer Control of Manufacturing Systems
8.	ME26038	Flexible manufacturing systems
9.	ME26040	Reliability engineering
10.	ME26042	Advanced Machining Processes
11.	ME26044	Lasers in Manufacturing Technology
12.	ME16026	Advanced Computational Fluid Dynamics
13.	ME46028	Optimization Methods for Engineering Design
14.	ME46036	Characterization of Engineering Materials
15.	ME46030	Robotics
16.	ME46038	Smart Materials and Sensors
17.	ME36032	Artificial Intelligence and Machine Learning for Mechanical Systems
18.	ME36030	Lean Manufacturing Systems
19.	ME26048	IIoT and Haptics
20.	ME36022	Supply Chain Management
21.	ME36024	Modelling and Simulation of Manufacturing Systems
22.	ME36026	Project Management
23.	ME36028	Materials and Process Selection for Design
24.	ME36036	Soft Computing Techniques
25.	ME36038	Drones and Autonomous Vehicles
26.	ME36040	Industrial Safety and Risk Management
27.	ME36042	Foundations of Lean Manufacturing
28.	ME26046	Precision Motion Control in CNC Applications
29.	ME46034	Design Thinking for Engineering Applications

The Overall Credit Structure

Course Category	Credits
Program Core	23
Professional Elective	15
Minor Project	2
Seminar and Technical Writing	2
Summer Internship/ Research Experience	2
ComprehensiveViva-Voce	2
Dissertation	20
Total Graded Credit Requirement	**66**

SYLLABI

M.Tech Manufacturing Engineering

1st Semester

ME26001 **3-0-0 (3)**

ADVANCED MANUFACTURING TECHNOLOGY

Pre-Requisites: None

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

CO1	Understand the advances in manufacturing processes including stir casting, cold metal transfer welding and inter pulse TIG welding
CO2	Apply the knowledge in welding of dissimilar materials and characterization by using Friction stir welding, laser and hybrid welding process
CO3	Design and analyze the component by WAAM and Powder bed fusion process
CO4	Apply advanced casting methods including stir casting and centrifugal casting for making composite materials and its characterization
CO5	Analyze the forming components using a high energy rate forming process

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Detailed Syllabus:

Advances in welding: Classification of solid state and fusion welding processes, Friction welding, process parameters, design of friction welded joints and applications, Friction stir welding: process parameters, tool design, selection of tool materials, fixture design, advantages, limitations and applications, Inter pulse TIG welding, cold metal transfer welding : effect of process parameters on weld strength, Electron beam welding process, Laser beam welding effect of process variables on mechanical properties of welded joints, Laser surfacing, laser hardening and cladding Hybrid welding process;-Process parameters, applications, advantages and limitations. Wire arc additive Manufacturing processes, the effect of build direction on mechanical properties, applications, advantages, and limitations and Powder Bed Fusion AM Processes.

Advances in casting: Introduction to advances in casting processes, Stir casting process, variables in stir casting process, stirrer design, factors affecting stir casting process, the effect of size and shape of the reinforcement particle in preparation of composite preparation, analysis of composite. Centrifugal casting, production of composites by centrifugal casting process, the effect of process variables on mechanical properties of composites, applications, advantages and limitations. Microwave casting advantages and limitations.

Advances in forming: Introduction forming processes, advantages, limitations and applications, Vacuum forming and hydroforming, the effect of process parameters on forming process, high energy rate forming process: Explosive forming, process parameters, design of explosive forming process, advantages and applications, High velocity forming and Mar forming, advantages and applications, Electromagnetic forming, process variables, advantages and applications.

Material characterization and design considerations: Optical microscopy, microhardness, SEM, and XRD analysis of AM and welded structures.

Learning Resources:

Textbooks:

1. R. S. Mishra, *Friction Stir Welding and Processing,* ASM International, 2007.
2. R.S.Parmar, Welding processes and Technology, Khanna Publishers, 2012
3. J Paulo Davim, *Modern Machining Technology, A Practical Guide*, 1st Edition, Woodhead Publishing in Mechanical Engineering
4. Materials Characterization, ASM Handbook, volume No 10, ASM International,1998
5. Casting , ASM Handbook, volume No 15, ASM International,1998
6. Forming , ASM Handbook, volume No 14, ASM International,1998

ME26005 **3-0-0 (3)**

MACHINING PHYSICS

Pre-Requisites: None

Course Outcomes:

CO1	Develop interrelations among ASA, ORS and NRS systems of tool geometry.
CO2	Analyse cutting forces, temperature, power and specific energy along the shear and rake planes in single point and multi point machining processes
CO3	Evaluate shear angle relationships and coefficient of friction in natural and controlled contact cutting
CO4	Analyse the cutting forces in Oblique machining process
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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed 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

Theories of Metal Cutting: 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, 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,

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

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

Learning Resources:

Textbooks:

1. M. C. Shaw, Metal Cutting - Principles and Practices, Cambridge University Press. 2005

2. A B Chattopadhyay, Machining and Machine Tools, 2ed, Wiley, 2017

3. P. N. Rao, Manufacturing Technology–Metal Cutting and Machine Tools, TMH, New Delhi, 2013

4. A. Bhattacharya, Metal Cutting: Theory and Practice, New Central Book Agency, Kolkata, 2007

5. V. K. Jain, Advanced Machining Processes, Allied Publisher, Mumbai, 2009

Reference Books:

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

2. P. C. Pandey and H. S. Shah, Modern Machining Processes, TMH, 1981

3. A Ghosh and AK Mallik, Manufacturing Science, EWP

4. B L Juneja and G S Sekhon, Fundamentals of Metal Cutting and Machine Tools, New Age International.

5. Helmi A Youssef and Hassan El-Hofy, Machining Technology – Machine Tools and Operations, CRC Press

6. The Machining of Metals, EJA Armarego & RH Brown, Prentice Hall

7. JE McGeough, Advanced Machining Methods, Pergamon Press

Other Suggested Readings:

1. NPTEL Lectures: https://nptel.ac.in/courses/112/105/112105126/

2. NPTEL Lectures: https://nptel.ac.in/courses/112/105/112105127/

ME26003 **3-0-0 (3)**

ADVANCED CAM AND INTELLIGENT MANUFACTURING SYSTEMS

PRE-REQUISITES: NONE

Course Outcomes:

CO1	Classify and distinguish NC, CNC and DNC systems
CO2	Assess the performance of manufacturing systems
CO3	Develop a systematic approach for design and implementation of manufacturing systems
CO4	Suggest new procedures to improve the productivity of existing manufacturing systems
CO5	Utilise online collaboration tools to work in complex teams

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Syllabus:

CNC Technology:

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

Computer Integrated Manufacturing Systems Structure and functional areas of CIM system - CAD, CAPP, CAM**,** CAQC, ASRS. Advantages of CIM. Manufacturing Communication Systems - MAP/TOP, OSI Model, Data Redundancy, Top- down and Bottom-up Approach, Volume of Information. Intelligent Manufacturing System Components, System Architecture and Data Flow, System Operation.

Knowledge Based Systems - Basic Components of Knowledge Based Systems, Knowledge Representation, Comparison of Knowledge Representation Schemes, Interference Engine, Knowledge Acquisition.

Machine Learning - Concept of Artificial Intelligence, Conceptual Learning, Artificial Neural Networks - Biological Neuron, Artificial Neuron, Types of Neural Networks, Applications in Manufacturing.

Automated Process Planning - Variant Approach, Generative Approach, Expert Systems for Process Planning, Feature Recognition, Phases of Process planning. Knowledge Based System for Equipment Selection (KBSES) - Manufacturing system design. Equipment Selection Problem, Modeling the Manufacturing Equipment Selection Problem, Problem Solving approach in KBSES, Structure of the KRSES.

Group Technology: Models and Algorithms Visual Method, Coding Method, Cluster Analysis Method, Matrix Formation - Similarity Coefficient Method, Sorting-based Algorithms, Bond Energy Algorithm, Cost Based method, Cluster Identification Method, Extended CI Method. Knowledge Based Group Technology - Group Technology in Automated Manufacturing System. Structure of Knowledge based system for group technology (KBST) — Data Base, Knowledge Base, Clustering Algorithm.

Learning Resources:

Text Books:

1. Intelligent Manufacturing Systems/ Andrew Kusiak/Prentice Hall.
2. Artificial Neural Networks/ Yagna Narayana/PHI/2006
3. Automation, Production Systems and CIM / Groover M.P./PHI/2007
4. Neural networks: A comprehensive foundation/ Simon Haykin/ PHI.
5. Artificial neural networks/ B. Vegnanarayana/PHI
6. Neural networks in Computer intelligence/ Li Min Fu/ TMH/2003
7. Neural networks/ James A Freeman David M S kapura/ Pearson education/2004
8. Introduction to Artificial Neural Systems/Jacek M. Zurada/JAICO Publishing House Ed. 2006.

ME26007 **3-0-0 (3)**

ADVANCED MANUFACTURING LABORATORY

Pre-Requisites: None

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

CO1	Analyze the microstructure in cast, welded and formed components
CO2	Analyze the mechanical properties of various components
CO3	Analyze the defective analysis and correlate to the mechanical properties
CO4	Analyze the Surface roughness of components
CO5	Analyze the additive manufacturing components

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	2	2		2	2	2
CO5	3	2	3	3	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

DETAILED DETAILED SYLLABUS:

1. Fabrication and characterization of components using Friction stir welding process (2 sessions)
2. Fabrication and characterization of components using WAAM process (2 sessions)
3. Fabrication and characterization of components using Powder bed fusion process (3 sessions)
4. Fabrication and characterization of components using stir casting and microwave casting
5. Fabrication and characterization of components using electrically assisted forming
6. Evaluating the formability of thin sheet by microforming
7. Evaluating the formability of thin sheet by Erichsen Cupping Test
8. To establish rolling on microstructure, mechanical and formability
9. The following Characterization are to be carried out on cast, welded and formed components (4)
    a. Analyze the microstructure of welded and cast components
    b. Identify the phases in the microstructure
    c. Phase/volume fraction
    d. Grain size measurement using line intercept method / area method
10. EDX-analysis using SEM
11. Tensile behavior of welded and additive manufactured components and draw the stress -strain curve
12. Fractography of welded and additive manufactured components
13. Microhardness analysis of welded and additive manufactured components
14. Demonstration of XRD Analysis
15. Analysis of additive manufactured components by using 3D-microscope
16. Demonstration of Polymer Printing Technologies
17. Post-processing of metal 3D Printed parts.

ME26009 **3-0-0 (3)**

MANUFACTURING AND PRECISION ENGINEERING LAB

Pre-Requisites: ME2605, ME2621

Course Outcomes:

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	Estimate type of fit for a given assembly and define tolerances
CO5	Estimate the compliance of M-F-T-W system
CO6	Evaluate form errors like straightness, flatness, squareness, roundness and circularity

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	2
CO4	3	2	2	2		2
CO7	3	2	2	2		2
CO8	3	2	2	2		2

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Syllabus:

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 average cutting temperature in turning process.
4. Estimation of tool life of a single point turning tool.
5. Evaluation of the effect of process parameters on MRR and Surface finish in EDM
6. Estimation of type of fit in assemblies
7. Define tolerances for a given assembly
8. Estimation of form errors like straightness, flatness and squareness on a machined component.
9. Evaluation of the accuracy of machine tools for parallelism of guideways, spindle runout, etc. in lathe, milling and drilling machines.
10. Production and evaluation of thread and gear profiles for their form and geometrical accuracies.
11. Precision measurement of form and geometrical accuracy of a sample using contact CMM
12. Precision measurement of form and geometrical accuracy of a sample using non-contact CMM
13. Simulation of turn components on CNC Simulator.
14. Turning of components on spinner.com lathe.

Learning Resources

Text Books:

1. Metal cutting-Principles and Practices, M. C. Shaw, Cambridge University press. 2005.
2. V.K. Jain, Advanced Machining Processes, 12th reprint, Allied Publishers Ltd, 2010.
3. Precision Engineering in Manufacturing, R.L.Murty, New Age International Publishers, 1996.
4. Lab instruction manual

2nd Semester

ME26002 **3-0-0 (3)**

ADDITIVE MANUFACTURING

Pre-Requisites: Nil

Course Outcomes:

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

CO1	Develop build preparation data for the additive manufacturing process
CO2	Identify properties of AM materials and their influence on final part quality
CO3	Describe the working principles and applications of each AM process
CO4	Apply design for AM guidelines to fabricate optimized components
CO5	Select the postprocessing and testing method for the given application

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

DETAILED DETAILED SYLLABUS:

Computer Aided Design (CAD) and Additive Manufacturing (AM) Build Preparation: Introduction to Geometric Modelling. Modelling of Synthetic Curves like Hermite, Bezier and B-spline; Parametric Representation of Freeform Surfaces and Solids. CAD Data Exchange Formats, Input File Sources and Characteristics, AM Data File Formats and Software, STL File Errors and Manipulation, AM Process Chain, Part Orientation and Support Generation, Model Slicing and Contour Data Organisation, Hatching Strategies, AM Toolpaths Generation and Process Plan, Build Preparation and AM Process Simulation.

AM Materials and Characterisation: Nature of Thermoplastics and Thermosetting Polymers, Properties of Metal and Ceramics. *AM Liquid Materials:* Rheology and Wetting Behaviour. *AM Solid Materials:* Filament Diameter Consistency, Density, Porosity, Moisture Content, Thermal Properties, Microstructure of Composite Filament, Mechanical Properties of Filament. *AM Powder Materials:* Powder Size Measurements, Morphology, Chemical Composition, Flow Characteristics, Density, Energy Absorption Characteristics of Powder.

Additive Manufacturing Processes: Classification of AM Processes. Description, Process Parameters, Strengths and Weaknesses of Vat Photopolymerization, Material Jetting, Binder Jetting, Material Extrusion, Sheet Lamination, Powder Bed Fusion and Directed Energy Deposition Processes; *Other Processes:* Aerosol Printing and Bio-plotter. *Construction of DIY Printers:* Motion System, Frame/Chassis, Print Bed, Extruder, Electronics.

Additive Manufacturing Applications: *Aerospace:* Aerospace Materials and their Requirements, Certification of AM Parts, Aerospace Case Studies. *Medical:* Medical Scanning Technologies, Planning and Simulation of Complex Surgeries, Medical Case Studies. *Automobile:* Prototyping, Jigs and Fixtures, Components of Electric Vehicles, Formula 1, Cooling Ducts, Intake Manifolds, Automobile Case Studies. *Other Applications of AM:* Marine, Railway, Oil and Gas, Construction, Retail Industry, Arts and Architecture, Fashion and Textile, Jewellery, Cion and Tableware, Weapons, Food, Packaging, and Toy Industry.

Design for AM (DfAM): Need for DfAM, AM Production Economics, General Guidelines for DfAM, Design to Minimize Print Time, Design to Minimize Post-processing, Design Guidelines for Part Consolidation, DfAM Guidelines for AM Tooling Design, Design for Improved Functionality, Design for Minimal Material Usage, Lattice Structures in AM, Generative Design and AM, Topology Optimization for AM, Polymer AM

Design Guidelines, Metal AM Design Guidelines, Modelling and Optimization of AM Processes, Guidelines for AM Process Selection.

Postprocessing and Testing of AM Parts: Need for Postprocessing in AM, *Surface Treatment Methods:* Subtractive Machining Methods, Thermal-based Methods, Abrasive-based Methods, Chemical Methods. *Surface Protection, Functionalization, and Decorative Methods.* Heat Treatment and Aging. Establish a Relationship between Processing Parameters, Resulting Microstructure, Mechanical Properties, Fatigue, Creep and Corrosion Resistance of AM Parts. *Testing of AM Parts:* Metrology Measurement Methods, Porosity and Density, Dimensions, Mechanical Measurement Methods, NDT Methods of AM Parts, AM Safety, AM Standards.

Learning Resources:

Textbooks:

1. Mathematical Elements for Computer Graphics, David F. Rogers, J. A. Adams, Tata McGrawHill, 2008.
2. A Guide to Additive Manufacturing, Damir Godec, Joamin Gonzalez-Gutierrez, Axel Nordin, Eujin Pei, Julia Urena Alcazar, Springer, 2022.
3. Additive Manufacturing Technologies, Ian Gibson, David Rosen, Brent Stucker, and Mahyar Khorasani, 3rd Edition, Springer, 2021.
4. A Practical Guide to Design for Additive Manufacturing, Diegel, Olaf, Axel Nordin, and Damien Motte, Springer, 2020.
5. Post-processing Techniques for Additive Manufacturing, Zafar Alam Faiz Iqbal, Dilshad Ahmad Khan, CRC Press, 2024.

Reference Books:

1. Geometric Modeling, Michael E.Mortenson, McGrawHill, 2013.
2. Rapid Prototyping: Laser-based and Other Technologies, Patri K. Venuvinod and Weiyin Ma, Springer, 2004.
3. Additive Manufacturing with Metals: Design, Processes, Materials, Quality Assurance, and Applications, Sanjay Joshi, Richard P. Martukanitz, Abdalla R. Nassar, Pan Michaleris, Springer, 2023.
4. Laser-Induced Materials and Processes for Rapid Prototyping, L.Lu, J. Y. H. Fuh and Y.S.Wong, Springer, 2001.
5. Rapid Prototyping: 3D Printing and Additive Manufacturing Principles & Applications, Chua Chee Kai, Leong Kah Fai, 5th Edition. World Scientific, 2019.
6. Handbook of Post-Processing in Additive Manufacturing: Requirements, Theories, and Methods, Gurminder Singh, Ranvijay Kumar, Kamalpreet Sandhu, Eujin Pei, and Sunpreet Singh, CRC Press, 2024.

ME26004 **3-0-0 (3)**

MECHATRONICS & AUTOMATION

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design and integrate mechanical and electrical systems to create functional mechatronic devices.
CO-2	Analyze and implement control systems using techniques like PID for automation applications
CO-3	Select and apply appropriate sensors and actuators for various mechatronic applications.
CO-4	Use programming languages and simulation tools for designing and testing automated systems.
CO-5	Develop innovative solutions to complex engineering challenges in mechatronics and automation.

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

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

Sensors and Actuators Static characteristics of sensors and actuators, Position, Displacement and Proximity Sensors, Force and torque sensors, Pressure sensors, Flow sensors, Temperature sensors, Acceleration sensors, Level sensors, Light sensors, Smart material sensors, Micro and Nano sensors, Selection criteria for sensors, Actuators: Electrical Actuators (Solenoids, Relays, DC motor, Servo motor, BLDC motor, AC motor, Stepper motors), Hydraulic and Pneumatic actuators, Design of Hydraulic and Pneumatic circuits, Piezoelectric actuators, Shape memory alloys.

Modelling, Analysis of Mechatronics Systems Basics of System Modelling: LTI and LTV systems, Need for modelling, Types of modelling, Steps in modelling, Building blocks of models, Modelling of one and two degrees of freedom systems, Modelling of Electro-mechanical systems, Mechanical Systems, Fluid systems, Thermal systems; Dynamic Responses, System Transfer Functions, State Space Analysis and System Properties, Stability Analysis using Root Locus Method, Stability Analysis using Bode Plots, PID Controllers.

Microcontrollers and Programmable Logic Controllers Logic Concepts and Design, System Interfaces, Communication and Computer Networks, Fault Analysis in Mechatronic Systems, Synchronous and Asynchronous Sequential Systems, Architecture, Microcontrollers, Programmable Logic Controllers (PLCs): Architecture, Number Systems Basics of PLC Programming, Logic gates, Timers and Counters, Application on real time industrial automation systems. Case studies: Design of pick and place robot, Car engine management system, Automated manufacturing system, Automatic parking system, Safety devices and systems.

Industry 4.0/5.0 Artificial Intelligence, Machine Learning, Cyber-Physical Systems, Advanced Control Strategies, Swarm Robotics, Human-Robot Interaction, Autonomous Vehicles, Smart Sensors, Internet of Things (IoT) integration, and Industry 4.0/5.0 technologies.

Learning Resources:

Textbooks:

1. W. Bolton, Mechatronics, *Electronic control systems in mechanical and electrical engineering,* Pearson Education, 7/e, 2023.

2. K P Ramachandran, GK Vijayaraghavan, M S Balasundaram, Mechatronics, Wiley, 4/e, 2019.

3. Mechatronics Systems Design, Devadas Shetty, Cengage Learning, USA, 2021.

Reference Books:

1. Mechatronics: A foundation course, Clarence W. de Silva, CRC Press, 2010

2. Robert H. Bishop. *The Mechatronics Handbook*, CRC Press, 2/e, 2007

3. David G. Alcaiatore and Michel B. Histand, *Introduction to Mechatronics and Measuring Systems*, Mc.Graw Hill Int. Edition, 6/e, 2022

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc21_me129/preview (Course by Prof. PS Gandhi, IITB)

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

3. http://mechatronics.me.wisc.edu

ME26006 **3-0-0 (3)**

MECHATRONICS & AUTOMATION LABORATORY

Pre-Requisites: Nil

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

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

List Of Experiments

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

Learning Resources:

Text Books

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

ME26008 **3-0-0 (3)**

MODELLING AND ANALYSIS LABORATORY

Pre-Requisites: Nil

Course Outcomes:

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

CO1	Create the components and their assembly using 3D modelling tools
CO2	Apply DfAM guidelines to develop the lightweight components
CO3	Analyse 1D/2D/3D structural components using FEA software
CO4	Investigate structural model analysis using topology optimization techniques
CO5	Prepare the build set-up for Polymer and Metal 3D Printing components

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

1 - Slightly; 2 - Moderately; 3 - Substantially

List of Experiments:

1. Selection of Component and Working with Sketch Mode using Solid Modelling Package (02 Sessions)
2. Assembling of Components with Appropriate Assembly Constraints (01 Session)
3. Design and develop the lightweight components using Design for Additive Manufacturing (DfAM) guidelines (02 Sessions)
4. Solving 1D Engineering Problems using FEA Package (01 Session)
5. Solving 2D and 3D Engineering Problems using FEA Package (02 Session)
6. Evaluation of Structural Component using Topology Optimization (02 Session)
7. Importing of STL file and Performing Part Orientation, Support Generation, etc., on Polymer Printing using FlashPrint Software (01 Session)
8. Build set-up Preparation for Intricate Metal Parts using 3DXpert Software (02 Sessions)

Learning Resources:

1) Manuals

ME26096 **3-0-0 (3)**

MINOR PROJECT

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world projects
CO-2	Plan and monitor project tasks individually or as a team
CO-3	Demonstrate practical experience in project execution
CO-4	Communicate project findings clearly through reports and presentations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3	3	
CO-2	2	2	2	2	2	
CO-3	2	2	2	2	2	
CO-4	1	1	1	1	1	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Identification of Problem Domain	
II	Study of Existing Systems and establishing clear objectives	
III	Planning of project and work distribution within the team	
IV	Proper Documentation and Technical Writing	
V	Presentation and Response to questions	

Evaluation Criteria-CO Mapping

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

3rd Semester

ME26089 **0-0-0 (2)**

SEMINAR & TECHNICAL WRITING

Pre-Requisites: **None**

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter 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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Clarity on the topic	
II	List of lectures attended	
III	Report	
IV	Presentation	
V	Response to questions	

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3
I	X		
II	X		
III		X	
IV			X
V			X

ME26091 **3-0-0 (3)**

SUMMER INTERNSHIP/RESEARCH EXPERIENCE

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	3		2	3
CO-2	2	1	2		2	3
CO-3		2				3
CO-4		3				3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Every student has to undergo either a Summer Internship / EPICS / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The EPICS/research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Relevance of the area of work	
II	Performance of the Task	
III	Crucial learnings from the work	
IV	Report Preparation	
V	Presentation and Response to questions	

Evaluation Criteria-CO Mapping

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

ME26093 **3-0-0 (3)**

COMPREHENSIVE VIVA-VOCE

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the knowledge gained in the course work
CO-2	Demonstrate the ability in problem solving
CO-3	Communicate effectively using engineering terminology

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3		
CO-2	3	3	3	3		
CO-3	2	2	2	2		

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

In Comprehensive viva-voce each student will be evaluated for their overall comprehension of the course work and laboratory training that they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots, schematics, write simple code etc. as questioned by the panel. Assessment will be done by the panel based on the student response.

ME26097 **0-0-0(8)**

DISSERTATION PART-A

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a topic in advanced areas of Manufacturing Engineering.
CO-2	Review literature to identify gaps and define objectives and scope of the work.
CO-3	Employ the ideas from literature and develop research methodology.
CO-4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	1		3
CO-2	3	2	3	1		3
CO-3	3	3	3	3	3	3
CO-4	3	3	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – A will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

The midterm review and the end semester viva-voce examination will be conducted by a committee constituted by the Head of the Department.

iv. The marks may be distributed among various components like selection of topic, problem statement, literature review, methodology, oral and written presentation of the work done and performance in viva-voce examination.
v. If the performance of the student in Dissertation Part-A is not satisfactory, he/ she will be awarded ‘F’ grade. The student has to repeat the dissertation work by registering in the next semester. Such students may be given an option either to continue with the same topic and with the same guide or change the guide and the topic of his/ her dissertation.

Evaluation Criteria

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Selection of Topic	
II	Literature Survey	
III	Defining the Objectives and Solution Methodology	
IV	Performance of the Task	

Evaluation Criteria - CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X

Refer to the M.Tech. – Regulations for any further information regarding mid-term review and end semester evaluation, etc.

4th Semester

ME26098 **0-0-0 (12)**

Dissertation-PART B

Pre-Requisites: **ME2697**

Course Outcomes:

CO-1	Identify the materials and methods for carrying out experiments/develop a code
CO-2	Execute the research methodology with a concern for society, environment and ethics
CO-3	Analyse, discuss and justify the results/trends and draw valid conclusions
CO-4	Prepare the report as per recommended format and present the work orally adhering to stipulated time
CO-5	Explore the possibility to publish/present a paper in peer reviewed journals/conference without plagiarism

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2		3	3	2	3
CO-2	2		3	3	2	3
CO-3	3		3	3	2	3
CO-4	3	3	3	3	3	3
CO-5	3	3	3			3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – B will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria as a continuation of Dissertation Part A. Weightage for each criterion will be determined by the panel and will be informed to the students.

Task	**Description**	**Weightages**
IV	Performance of the Task	
V	Dissertation Preparation	
VI	Review (Presentation & Understanding)	
VII	Viva-Voce	
VIII	Publications /Possibility of publication	

Evaluation Criteria-CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4	CO5
IV	X	X			
V				X	
VI			X		
VII				X	
VIII					X

Refer to the M.Tech. – “Refer to M.Tech. – Regulations for any further information regarding Mid-term review, End Sem evaluation, Template for report preparation and plagiarism”

Professional Electives

ME26021 **3-0-0 (3)**

PRECISION ENGINEERING

Pre-Requisites: **Nil**

Course Outcomes:

CO1	Evaluate the part and machine tool accuracies.
CO2	Understand principles of ultra-precision machining, micro-manufacturing methods, and additive manufacturing.
CO3	Understand advanced metrology tools and techniques to measure and analyze components with high precision.
CO4	Understand the principles and techniques of nanotechnology to develop and analyze nanoscale materials and devices for various applications
CO5	Design and apply fits and tolerances using principles of dimensional chains for individual features for parts and assemblies according to ISO standards.

CO-PO Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed 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.

Precision Manufacturing: Micro machining processes-Diamond machining - Micro engraving - Micro replication techniques-Forming, Casting, Injection molding - Micro embossing. Methods of obtaining high quality surfaces, Lapping, Honing, Super finishing and Burnishing processes. Limitation of conventional manufacturing, Unconventional manufacturing methods - LBM, EBM, FIB, Micro electro discharge machining-photolithography-LIGA process- Silicon Micro Machining-Wet and dry etching-thin film deposition, applications – Smart Sensors, MEMS, Optical Components and Microfluidic devices.

Precision Metrology- In situ measurement- In process measurement of position of processing Point-Post process and online measurement of dimensional features- Mechanical measuring systems- Optical Measuring Systems- Optical Interferometry, Laser Scanning, White Light Interferometry Confocal Microscopy, Electron beam measuring Systems-Scanning Tunnelling-Atomic Force Microscope and X-Ray Computed Tomography. Surface Metrology-Surface Roughness and Measurement, Quality assurance

Nano precision technology: Fundamentals of nanotechnology, Nano physical processing of atomic-bit-units Nano chemical and electrochemical atomic-bit processing. –Nano-Grating systems –Nano lithography, Electron beam lithography –Mirror grinding of ceramics, Focused Ion Beam (FIB) Milling, Atomic Layer Deposition (ALD), Nano processing of materials for super high-density ICs-Nano-mechanical parts, Nano machines-NEMS, Applications- Nanoelectronics, Nanocomposites and nano coatings.

Geometric Dimensioning and Tolerancing: Tolerance and fits, Hole and shaft basis system, Types of fits- Types of assemblies-probability of clearance and interference fits in transitional fits, Concept of dimensional chain or tolerance stack. Dimensioning of stepped shaft and holes assigning tolerances on the constituent dimensions. Tolerance zone conversions-surfaces, Datum - Datum feature of representation-form controls, Logical approach to tolerancing-datum systems, Geometrical tolerances.

Learning Resources:

Text Books:

1. R.L.Murty, ”Precision Engineering in Manufacturing”, New Age International Publishers, 1996.
2. James, D. and Meadow, S., “Geometric Dimensioning and Tolerancing”, Marcel Dekker Inc.,1995.

Reference Books:

1. V.Kovan, "Fundamentals of Process Engineering", Foreign Languages Publishing House, Moscow, 1975
2. J.L.Gadjala, "Dimensional control in Precision Manufacturing", McGraw Hill Publishers.
3. Norio Tanigichi “Nano Technology”, oxford university press, 2003.
4. Venkatesh, V.C. and Sudin, I., “Precision Engineering”, Tata McGraw Hill Co., NewDelhi, 2007.
5. Liangchi Zhang, “Precision Machining of Advanced Materials”, Trans Tech Publications Ltd., Switzerland, 1st Edition, 2001.
6. X. Jane Jiang, Paul J. Scott, “Advanced Metrology: Freeform Surfaces”, Academic Press Inc, April 2020.

ME26023 **3-0-0 (3)**

MECHANICAL BEHAVIOR AND CHARACTERIZATION OF MATERIALS AND NDT

Pre-Requisites: **Nil**

Course Outcomes:

CO1	Understand the mechanical behaviour of ductile and brittle materials
CO2	Analyse creep, fatigue and fracture mechanisms for various materials
CO3	Develop fracture mechanism maps and analyse the reasons for failure of materials
CO4	Select a characterization technique to evaluate the behaviour of materials

CO-PO Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Introduction: A brief review of elastic and plastic deformation, dislocations and their properties. Dislocations in FCC, BCC and HCP metals, interactions with point defects and other dislocations. Tensile behavior, evaluation of strength and ductility parameters, Effect of strain rate and temperature on tensile behavior, and Protevin Le-Chatelier effect.

Creep: Types and mechanisms of creep deformation, Creep under combined stresses, deformation mechanism maps, Super plasticity, environmental effects, remaining life assessment.

Fatigue: High and low cycle fatigue, process of fatigue fracture, effect of mean stress, Cyclic stress/strain response of materials, establishment of cyclic stress/ strain curve, transition fatigue life, Coffin-Manson relationship, Evaluation of parameters, characterizing resistance against high cycle and Low cycle fatigue, Creep fatigue interaction, environmental effects, thermochemical fatigue.

Fracture Mechanics: Brief review of the basic concepts of linear elastic and elastic-plastic fracture mechanics, stress intensity parameter, J- integral and crack tip opening displacement as fracture criteria, standard procedures for experimental determination of these parameters.

Failure analysis: Analyzing Fractures, Micro mechanisms of brittle and ductile fracture, fracture mechanism maps, fractography, Visual Examination & Management of Applied Failure Analysis, Manage Failure Analysis.

Materials characterization techniques and NDT Optical microscopy techniques, Quantitative metallography Scanning electron microscopy: Image formation methods in SEM. Applications. Liquid penetrant test, Ultrasonic test, eddy current test, Magnetic particle testing, Radiography

Learning Resources:

Textbooks:

1. George E. Dieter, Mechanical Metallurgy, McGraw Hill, 2nd Edition, 2005.

2. Hellan K, Introduction to Fracture Mechanics, McGraw Hill, 2002

3. J.E.Dorn, Mechanical Behavior of Materials at Elevated Temperatures, McGraw Hill, 2000.

4. M.F Ashby and David R H Jones : Engineering Materials I : Introduction to Properties, Applications and Design,2010 5. Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, 5th Edition, Wiley, 2012

ME26025 **3-0-0 (3)**

MICRO AND NANO MANUFACTURING

Pre-Requisites: **NONE**

Course Outcomes:

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:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	–	3	3	–	–
CO-2	3	–	3	3	–	–
CO-3	3	–	3	3	–	–
CO-4	3	2	3	3	–	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Syllabus:

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

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.

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

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

Nanofabrication Techniques: Laser based nano manufacturing, 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:

Textbooks:

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.

ME26027 **3-0-0 (3)**

MECHANICS OF METAL FORMING

Pre-Requisites: **Nil**

Course Outcomes:

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

CO-PO Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed 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

Wire Drawing Processes: Introduction, wire drawing load calculation

Deep Drawing Processes: Introduction, determination of drawing force and power in deep drawing

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

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, formability of tailor welded blanks, formability of friction stir welding sheets, incremental sheet forming, and electric assisted 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, modelling to predict the strains and formability

Case studies: Case studies on the manufacturing aspects of products using the lessons learnt and practical applications of metal forming

Learning Resources:

Textbooks:

1. Surender Kumar, Technology of Metal Forming Processes, Prentice - Hall, Inc., 2008.
2. Henry S. Valberg, Applied Metal Forming - Including FEM Analysis, Cambridge University Press, 2010.
3. Metal Forming: Mechanics and Metallurgy by William F. Hosford and Robert M. Caddell, Prentice-Hall (USA) – 2012

ME26031 **3-0-0 (3)**

SURFACE ENGINEERING

Pre-Requisites: **None**

Course Outcomes:

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.

CO-PO Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

DETAILED DETAILED 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, compositionally complex coatings, smart coating.

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 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 Handbook – 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/

ME26033 **3-0-0 (3)**

DESIGN AND ANALYSIS OF MACHINE TOOLS

Pre-Requisites: ME2633

Course Outcomes:

CO-1	Design kinematic motions in a machine tool.
CO-2	Design speed and feed gear boxes.
CO-3	Design machine tool structures for strength and rigidity.
CO-4	Analyze machine tool vibration and chatter.
CO-5	Select alignment tests to be performed on a machine tool for quality assurance.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	–	3	3	–	–
CO-2	3	–	3	3	–	–
CO-3	3	–	3	3	–	–
CO-4	3	2	3	3	–	–
CO-5	3	3	3	2	–	–
CO-6	3	–	3	2	–	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed 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 Speeds and Feeds: 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, Power Screws and Spindles: Functions and Types of Guideways, Design of Guideways, Design of Aerostatic Slideways, Design of Anti-Friction Guideways, Combination Guideways, 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

Acceptance Tests: International standards, Indian standards, Characterization of machine tools.

Learning Resources:

Textbooks:

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
3. Boothroyd, G., “Fundamentals of Metal Machining and Machine Tools”, McGraw hill.

Reference Books:

1. Design Principles of Metal Cutting Machine tool - F. Koenigsberger - Pergamon press
2. Machine Tool design Handbook CMTI Bangalore, McGraw-Hill
3. Acherkan, “Machine Tool Design”, Vol 2 & 3, MIR Pub, Russia

ME26035 **3-0-0 (3)**

FINITE ELEMENT APPLICATIONS IN MATERIALS PROCESSING

Pre-Requisites: None

Course Outcomes:

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

CO1	Apply finite element method to solve problems in solid mechanics
CO2	Formulate FE characteristic equations for two dimensional elements and analyze plain stress, plain strain, axi-symmetric and plate bending problems.
CO3	Solve heat transfer and fluid mechanics problems using the principles of FEM.
CO4	Analyze deformation processes using finite element principles.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Detailed Syllabus:

Introduction to FEA, Stresses and equilibrium, Strain displacement relations, Potential energy and equilibrium, FEA in 1 D problems: Element division, Numbering scheme, coordinates and shape functions - Galerkin Approach, Assembly of the global stiffness matrix and load vector, 1 D Problems, Temperature effects.

FEA in 2 D 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, subparametric, Isoparametric and superparametric elements. Formulation of plate bending elements using linear and higher order bending theories, Shell elements. Exercises on structural, flow and heat transfer problems.

Non Linear FEA – Introduction to Non Linear Finite Element Analysis – Nonlinearities – Solution Methods – Newton Raphson – Modified Newton Raphson – Secant Method – Incremental Force Method - Problems

FEA of Elasto Plastic Problems – One and Multidimensional Elastoplasticity – Yield Criteria – Hardening Models – Mathematical Formulations - Problems

FEA in Heat Transfer problems: Finite element solution for one dimensional heat conduction with convective boundaries. Formulation of element characteristics and simple numerical problems. Formulation for 2-D problems with convective boundaries, Problems.

Learning Resources:

Textbooks:

1. Henry S Valberg, Applied Metal Forming: Including FEM Analysis, Cambridge Press. 2010
2. Nam Ho Kim, Introduction to Non-Linear Finite Element Analysis, 2015, Springer.

3. C. R. Boer· N. Rebelo H. Rydstad . G. Schroder, Process Modelling of Metal Forming and Thermomechanical Treatment, Springer-Verlag, 1986.

Reference Books:

1. S S Rao, *The Finite Element Method in Engineering*, 4th Edition, Elsevier 2007.
2. Reddy, J.N., *Finite Element Method in Engineering*, Tata McGraw Hill, 2007.

ME26037 **3-0-0 (3)**

COMPUTATIONAL MODELING OF MATERIALS

Pre-Requisites:

- Basic knowledge of materials science and engineering
- Basic programming skills (Python preferred)
- Fundamental understanding of linear algebra, calculus, and statistics

Course Outcomes:

CO-1	Select an appropriate method for simulation considering length and time scale
CO-2	Develop a deep understanding of fundamental principles in materials modeling and simulation
CO-3	Apply modeling and simulation techniques to solve real-world materials science problems
CO-4	Make use of different scale modeling techniques to solve materials problem
CO-5	Gain proficiency in computational techniques such as first-principles calculations, molecular dynamics, and Monte Carlo methods

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	1		3	
CO-2	3	3	1		3	
CO-3	3	3	3		3	
CO-4	3	3	3	3	3	
CO-5	3	3	2	3	3	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Introduction to materials modeling and simulation: Modeling and simulation, scales in materials structure and behavior, how to develop models, Applications and importance, material modeling techniques, basic of material science, basic of statistical thermodynamics, Access to materials science databases and software

Computational materials modelling form first principles: Fundamentals of atomistic simulation method, Density functional theory, The Many-body Schrodinger Equation, Kohn-Sham Equation, Pseudopotential method. Properties calculation from first-principle calculations: Lattice parameter, Thermodynamics properties above 0 K, Elastic properties, Defect Properties

Molecular dynamics simulations: The basic mechanical quantities in MD, Periodic boundary condition, Time integration algorithm, ensemble, Procedure of MD simulation, Empirical Force field models, Ab Initio MD simulation, machine learning interatomic potentials

Monte Carlo simulation methods: Introduction of Monte Carlo simulation methods, calculating properties by integration, Theoretical background of the Monte Carlo method, Implementation of the Monte Carlo method, Monte Carlo Sampling from different ensembles

Cluster Expansion: Fundamentals of cluster expansion**,** Applications in alloy thermodynamics and phase diagrams, Computational tools for cluster expansion**,**

Continuum modeling: Introduction to continuum mechanics, Introduction to finite element method (FEM), FEM of materials deformation, FEM of materials failure.

Multiscale Modeling: Bridging different length and time scales, Coupling atomistic and continuum models, Applications in complex materials systems

Solving Problems Using Computer Code: Design of an ultra-lightweight Mg-Li alloys using First principles calculations**,** Calculation of diffusion coefficient using Ab Initio MD simulations, Mechanical Properties using MD simulations of binary alloys, Mechanical Properties using MD simulations of carbon nanotube (CNT) based nanocomposite

Learning Resources:

Text Books:

1. Feliciano Giustino, Materials Modeling Using Density Functional Theory: Properties and Predictions, Oxford University Press, 2014, 1st Edition.
2. Richard Lesar, Computational Materials Science: Fundamentals to Applications, Cambridge University Press, 2013, 1st Edition.
3. Daan Frenkel and Berend Smit, Understanding Molecular Simulation: From Algorithms to Applications, Academic Press, 2002, 2nd Edition.
4. Rob Phillips, Crystals, Defects, and Microstructures: Modeling Across Scales, Cambridge University Press, 2001, 1st Edition

Reference Books**:**

1. Wolfram Koch and Max C. Holthausen, A Chemist's Guide to Density Functional Theory, Wiley-VCH, 2001, 2nd Edition.
2. Mark Tuckerman, The Art of Molecular Dynamics Simulation, Oxford University Press, 2010, 2nd Edition

Other Suggested Readings:

1. NPTEL Courses: Foundations of Computational Materials Modelling. By Prof. Narasimhan Swaminathan: https://archive.nptel.ac.in/courses/112/106/112106289/

ME26039 **3-0-0 (3)**

PRODUCT DESIGN AND ASSEMBLY AUTOMATION

Pre-Requisites: **None**

Course Outcomes:

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

CO1	Understand the fundamentals of product design and assembly automation.
CO2	Apply principles of design for automation to product development.
CO3	Analyze and select appropriate automation technologies for assembly processes.
CO4	Evaluate the economic and operational impacts of assembly automation.
CO5	Design products that are optimized for automated assembly.

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Course Articulation Matrix:

CO	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

Detailed Detailed 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 *as*sembly systems, Quantitative analysis of Assembly systems, Multi station assembly systems, single station assembly lines.

Learning Resources:

Textbooks:

1. Geoffrey Boothroyd, *Assembly Automation and Product Design*, Marcel Dekker Inc., NY, 3rd Edition,2010.
2. Geoffrey Boothroyd, *Hand Book of Product Design*, Marcel Dekker Inc., NY, 1992.

ME26041 **3-0-0 (3)**

OPERATION MANAGEMENT

Course Outcomes:

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

CO1	Design of production planning and control systems encompassing competitivepriorities 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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed 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.

Learning Resources:

Textbooks:

1. “Operation Management, Author- Joseph G Monks McGrew Hill Publication, International Edition-1987.

2. “Production and Operation Management”, Author-Pannerselvam R. PHI publications, 2nd edition

3. “An Introductory book on lean System, TPS Yasuhiro Modern.

Reference Books:

1. “Production and Operation Management” Chary S. N. TataMcGrew Hill 5th edition 2019

2. “Production and Operations Management”, Everett E. Adams, Ronald J. Ebert, Prentice Hall of India Publications, 5th Edition.

3. Modern Production/Operations Management, Buffia, Wiely India Ltd 8th Edition.

ME26043 **3-0-0 (3)**

Microwave Materials Processing: Principles and Applications

Pre-Requisites: Basic Physics (Electromagnetism, Heat Transfer), Engineering Materials, and Thermodynamics

Course Outcomes:

CO1	Explain the principles of microwave generation, propagation, and interaction with different classes of materials.
CO2	Analyze the thermal, electromagnetic, and dielectric behavior of materials under microwave fields.
CO3	Design and evaluate microwave-assisted systems and processes for applications such as sintering, curing, drying, and synthesis.
CO4	Integrate interdisciplinary knowledge from electrical, mechanical, civil, chemical, and materials engineering to develop innovative and sustainable processing solutions.
CO5	Assess the efficiency, environmental impact, and industrial relevance of microwave processing compared to conventional techniques.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Microwave Processing: Overview of electromagnetic energy and microwave spectrum, Fundamentals of microwave heating, Conventional vs microwave heating: energy and kinetics comparison, Interaction of microwaves with materials, Dielectric properties and their significance. Multidisciplinary applications overview: Civil: microwave curing of concrete, asphalt drying, Mechanical: Microwave Heating, Microwave Drying, Microwave Welding, Microwave Sintering / Metallurgy, Microwave Cladding / Coating, Microwave-Assisted Machining, Microwave-Assisted Chemical Processing, Electrical: dielectric heating, electronic materials, Chemical/Materials: synthesis, waste processing

Fundamentals of Microwave Generation & Propagation: Sources: magnetrons, solid-state generators, Transmission: waveguides, cavities, resonant modes, Electric and magnetic field distribution, Instrumentation and power measurement, Electrical and electronics design perspective: impedance matching, power control

Interaction of Microwaves with Materials: Dielectric properties: permittivity, loss tangent, penetration depth, safety/shielding, hybrid heating, and frequency selection., Factors affecting microwave absorption (temperature, composition, moisture), Measurement methods for dielectric properties, interaction with polymers, interaction with ceramics, interaction with metals and non-metals.

Thermo-Mechanical Aspects of Microwave Heating: Coupled electromagnetic–thermal behaviour, Nonuniform heating, hot spots, and thermal stresses, Modelling of heat transfer and stress using FEA tools (COMSOL/ANSYS), Application examples: Microwave drying of cement and wood, Rapid sintering of metal and ceramic components

Learning Resources

Textbooks & References:

1. Advances in Microwave Processing for Engineering Materials, Edited By Amit Bansal, Hitesh Vasudev(1st Edition),CRC Press, Taylor & Francis Group
2. Microwave Chemical and Materials Processing, A Tutorial. Authors: Satoshi Horikoshi, José M. Catalá-Civera, Robert F. Schiffmann, Jun Fukushima,Tomohiko Mitani, Nick Serpone
3. Microwaves and Metals by M. Gupta, Manoj Gupta, and Eugene Wong Wai Leong
4. Microwave Engineering of Nanomaterials from Mesoscale to Nanoscale ,Edited By Erwann Guenin
5. Microwave Materials and Applications, 2 Volume Set, Sebastian, Mailadil T. / Ubic, Rick / Jantunen, Heli (Editor)
6. Advances in Microwave Engineering from Novel Materials to Novel Microwave Applications, Edited By Ankan Bhattacharya, Bappadittya Roy, Arnab De, Ujjal Chakraborty, Anup Kumar Bhattacharjee
7. Microwave Applications in Chemical Engineering.Edited byKama Huang, Junwu Tao, Huacheng Zhu.
8. Microwave Assisted Synthesis of Materials author: Charu Lata Dube

Online Resources:

1. https://www.youtube.com/watch?time_continue=31&v=dd5BlyCwpt0&embeds_referring_euri=https%3A%2F%2Fwww.bing.com%2F&embeds_referring_origin=https%3A%2F%2Fwww.bing.com&source_ve_path=Mjg2NjY
2. Applications and new trends in Microwave Material Processing
3. https://www.youtube.com/watch?v=IES-Ik8x3E0
4. https://www.youtube.com/watch?v=ppHSqhX9e_Q
5. https://www.comsol.com/support/learning-center/article/Getting-Started-with-Electro-Thermal-Mechanical-Modeling-10561/82

ME26045 **3-0-0 (3)**

Artificial Intelligence and Machine Learning in Materials Engineering

Pre-Requisites: None

Course Outcomes:

CO-1	Explain the fundamentals of materials structure, processing, and structure–property relationships relevant to materials design
CO-2	Implement and evaluate machine learning models by applying supervised and unsupervised algorithms
CO-3	Apply statistical and machine learning techniques for materials data analysis and property prediction.
CO-4	Use computer vision and AI methods to establish microstructure–property correlations and support data-driven materials design.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	3	2	-	-
CO-2	1	2	1	2	-	-
CO-3	-	-	2	3	-	-
CO-4	-	-	3	2	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Fundamentals of Materials science and Processing: Introduction to AI/ML in Materials Engineering: motivation and scope, Structure of materials: atomic, crystalline, and defect structures, Microstructure and property relationships, Processing of materials: solidification, deformation, heat treatment, Correlation between processing, structure, and properties

Fundamentals of Machine Learning: Supervised learning – Regression, Support Vector Machine, Random Forest; Cost functions and optimization; Feature engineering, model training and model validation; Classification metrics; Unsupervised learning – Clustering

Machine Learning for Materials Design: Materials databases, Materials datasets, Materials descriptors, Statistical analysis and data handling in materials science, Data generation using simulations and data integration, Machine learning for materials applications – case studies: Materials property prediction, Phase prediction of high entropy alloys

Advanced AI Applications in Materials Engineering: Machine learning for microstructural evolution modeling, ML-based microstructure property correlations, Computer vision techniques for microstructure analysis, Case studies and recent advances in AI-driven materials design

Learning Resources:

Text Books:

1. Materials Informatics: Data-Driven Discovery in Materials Science by Krishna Rajan, Springer, First Edition, 2015.
2. Machine Learning in Materials Science by A. Agrawal and A. Choudhary, Elsevier, First Edition, 2016.
3. Computational Materials Science: An Introduction by June Gunn Lee, CRC Press, Second Edition, 2017.

4. Data-Driven Materials Science and Engineering by Turab Lookman, K. Rajan, and A. Saxena, Elsevier, First Edition, 2016.
5. Artificial Intelligence for Materials Science by Taylor Sparks, Morgan & Claypool Publishers, First Edition, 2020.

Reference Books:

1. Jake VanderPlas, "Python Data Science Handbook: Essential Tools for Working with Data, O'Reilly Media, 1st Edition, 2016
2. Machine Learning: A Probabilistic Perspective by Kevin P. Murphy, MIT Press, First Edition, 2012.
3. Pattern Recognition and Machine Learning by Christopher M. Bishop, Springer, First Edition, 2006.
4. Computational Materials Engineering by Koenraad George Frans Janssens et al., Elsevier, First Edition, 2017.
5. Multiscale Materials Modeling by Z. X. Guo and W. Sha, Woodhead Publishing, First Edition, 2010.
6. Introduction to Computational Materials Science by Richard LeSar, Cambridge University Press, Second Edition, 2013.

Other Suggested Readings:

1. NPTEL Courses: Machine Learning for Engineering and Science Applications By Prof. Balaji Srinivasan and Prof. Ganapathy
2. https://jarvis.nist.gov/

ME16027 **3-0-0 (3)**

ENERGY SYSTEMS AND MANAGEMENT

Prerequisites: NIL

Course Outcomes:

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

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Syllabus:

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

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

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

Heat recovery systems: Incinerators, regenerators and boilers

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

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

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

Learning Resources:

Text Books:

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

Reference Books:

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

Online Resources:

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

ME46021 **3-0-0 (3)**

COMPUTER-AIDED GEOMETRIC DESIGN

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply geometric transformations and projection methods in CAD
CO-2	Develop geometric models to represent curves
CO-3	Design surface and solid models for engineering design
CO-4	Apply mesh generation techniques for engineering analysis

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3		3	3	2	2
CO-2	3		3	3	2	2
CO-3	3	2	3	3	3	2
CO-4	3	2	3	3	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

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

Transformations in Geometric Modeling: Introduction, Translation, Scaling, Reflection, Rotation in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations. Computer-Aided assembly of rigid bodies, Applications of transformations in design and analysis of mechanisms, etc. Implementation of the transformations using computer codes.

Projections: Projective geometry, transformation matrices for Perspective, Axonometric projections, Orthographic and Oblique projections. Implementation of the projection formulations using computer codes.

Introduction to Geometric Modeling for Design: Introduction to CAGD, CAD input devices, CAD output devices, CAD Software, Display Visualization Aids, and Requirements of Modelling.

Curves in Geometric Modeling for Design: Differential geometry of curves, Analytic Curves, PC curve, Ferguson's Cubic Curve, Composite Ferguson, Curve Trimming and Blending. Bezier segments, de Casteljau's algorithm, Bernstein polynomials, Bezier-subdivision, Degree elevation, Composite Bezier. B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS, Conversion of one form of curve to other. Implementation of the all the curve models using computer codes in an interactive manner.

Surfaces in Geometric Modeling for Design: Differential geometry of surfaces, Parametric representation, Curvatures, Developable surfaces. Surfaces entities (planar, surfac of revolution, lofted etc). Free-for surface models (Hermite, Bezier, B-spline surface). Boundary interpolating surfaces (Coon's). Implementation of the all the surface models using computer codes.

Solids in Geometric Modeling for Design: Solid entities, Boolean operations, Topological aspects, Invariants. Write-frame modeling, B-rep of Solid Modelling, CSG approach of solid modelling. Popular modeling methods in CAD softwares. Data Exchange Formats and CAD Applications:

Meshing Methods for Engineering Analysis: FEM, Meshing, Quality of meshing, Mesh generation methods

Learning Resources:

Text Books:

1. Michael E. Mortenson, Geometric Modeling, Tata McGraw Hill, 2013.
2. Saxena and B. Sahay, Computer-Aided Engineering Design, Anamaya Publishers, New Delhi, 2005.

Reference Books:

1. Rogers, David F.Morgan, An introduction to NURBS: with historical perspective, Kaufmann Publishers, USA, 2001.
2. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, TMH, 2008.
3. Kunwoo Lee, Principles of CAD/CAM/CAE systems, Addison-Wesley, 1999.

ME46027 **3-0-0 (3)**

MATHEMATICAL METHODS IN ENGINEERING

Pre-Requisites: **None**

Course Outcomes:

CO-1	Extend the methods of Applied Linear Algebra to engineering design problems
CO-2	Solve problems involving Nonlinear Optimization in engineering
CO-3	Simulate engineering systems using Numerical Methods.
CO-4	Model physical systems using Differential Equations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	3	1	2
CO-2	2	2	3	3	2	2
CO-3	3		3	3	3	2
CO-4	3		3	3	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Solution of Systems of Linear Equations: Introduction, Basic Ideas of Applied Linear Algebra, Systems of Linear Equations, Square, Non-Singular Systems, ILL-Conditioned and ILL-Posed Systems.

The Algebraic Eigenvalue Problem: The Algebraic Eigenvalue Problem, Canonical Forms, Symmetric Matrices, Methods of Plane Rotations, Householder Method, Tridiagonal Matrices, QR Decomposition, General Matrices.

Selected Topics in Linear Algebra and Calculus: Singular Value Decomposition, Vector Space: Concepts, Multivariate Calculus, Vector Calculus in Geometry, Vector Calculus in Physics.

An Introductory Outline of Optimization Techniques: Solution of Equations, Introduction to Optimization, Multivariate Optimization, Constrained Optimization: Optimality Criteria, Constrained Optimization: Further Issues.

Selected Topics in Numerical Analysis: Interpolation, Regression, Numerical Integration, Numerical Solution of ODE's as IVP Boundary Value Problems, Question of Stability in IVP Solution, Stiff Differential Equations, Existence and Uniqueness Theory.

Ordinary Differential Equations: Theory of First Order ODE's, Linear Second Order ODE's, Methods of Linear ODE's, ODE Systems, Stability of Dynamic Systems.

Application of ODE's in Approximation Theory: Series Solutions and Special Functions, Sturm-Liouville Theory, Approximation Theory and Fourier Series, Fourier Integral to Fourier Transform, Minimax Approximation.

Overviews: PDE's, Complex Analysis and Variational Calculus: Separation of Variables in PDE's, Hyperbolic Equations, Parabolic and Elliptic Equations, Membrane Equation, Analytic Functions, Integration of Complex Functions, Singularities and Residues, Calculus of Variations.

Learning Resources:

Text Books:

1. B. Dasgupta, Applied Mathematical Methods, Pearson Education, 2006.
2. E. Kreyszig , Advanced Engineering Mathematics, Wiley, 2010.

Reference Books:

1. M. T. Heath, Scientific Computing, McGraw-Hill Education, 2001.
2. Steven Chapra, Applied Numerical Methods with Matlab, McGraw-Hill Education, 2011.

ME36029 **3-0-0 (3)**

ADVANCED CAD

Pre-Requisites: Nil

Course Outcomes:

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

CO1	Understand conceptual design and geometric transformation techniques in CAD
CO2	Develop mathematical models to represent synthetic 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		3	2	2	
CO3	3		3	3	2	
CO4	2		2	2	2	

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Detailed Syllabus:

Introduction: Introduction to Computer Aided Engineering (CAE), Computer Aided Design (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:

Textbooks:

1. Mathematical Elements for Computer Graphics, David F. Rogers, J. A. Adams, TMH, 2008.
2. Geometric Modelling, 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, Anupam Saxena, Birendra Sahay, Springer, 2005.

ME36021 **3-0-0 (3)**

3D PRINTING TECHNOLOGIES

Pre-Requisites: **None**

Course Outcomes:

CO1	Develop preprocess data for the 3D Printing
CO2	Identify properties of 3DP materials and their influence on final part quality
CO3	Describe the working principles of each 3D Printing technology
CO4	Apply suitable 3D Printing technology for any given industrial application
CO5	Select the postprocessing and testing method for the given application

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
CO5	3	3	3	2	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Computer Aided Design (CAD) and Preprocessing Data for 3D Printing: Introduction to Geometric Modelling. Modelling of Synthetic Curves like Hermite, Bezier and B-spline; Parametric Representation of Freeform Surfaces and Solids. CAD Data Exchange Formats, Input File Sources and Characteristics, 3D Printing Data File Formats and Software, STL File Errors and Manipulation, 3D Printing Process Chain, Part Orientation and Support Generation, Model Slicing and Contour Data Organisation, Hatching Strategies, 3D Printing Toolpaths Generation and Process Plan, Build Preparation and 3D Printing Process Simulation.

3D Printing Materials and Characterisation: Nature of Thermoplastics and Thermosetting Polymers, Properties of Metal and Ceramics. *3DP Liquid Materials:* Rheology and Wetting Behaviour. *3DP Solid Materials:* Filament Diameter Consistency, Density, Porosity, Moisture Content, Thermal Properties, Microstructure of Composite Filament, Mechanical Properties of Filament. *3DP Powder Materials:* Powder Size Measurements, Morphology, Chemical Composition, Flow Characteristics, Density, Energy Absorption Characteristics of Powder.

3D Printing Processes: Classification of 3D Printing Processes. Description, Process Parameters, Material Selection and Characterisation, Applications, Strengths and Weaknesses of Vat Photopolymerization, Material Jetting, Binder Jetting, Material Extrusion, Sheet Lamination, Powder Bed Fusion and Directed Energy Deposition Processes; *Other Processes:* Aerosol Printing and Bio-plotter. *Construction of DIY Printers:* Motion System, Frame/Chassis, Print Bed, Extruder, Electronics.

3D Printing Applications: An Overview of 3D Printing Applications, *Aerospace:* Aerospace Materials and their Requirements, Qualification and Certification of Parts, Aerospace Case Studies. *Medical:* Medical Scanning Technologies, Biomaterials, Planning and Simulation of Complex Surgeries, Design and Fabrication of Customized Implants, Medical Case Studies. *Automobile:* Prototyping, Jigs and Fixtures, Components of Electric Vehicles, Formula 1, Cooling Ducts, Intake Manifolds, Automobile Case Studies. *Other Applications of 3DP:* Marine, Railway, Oil and Gas, Construction, Retail Industry, Arts and

Architecture, Fashion and Textile, Jewellery, Cion and Tableware, Weapons, Food, Packaging, and Toy Industry.

Postprocessing and Testing of 3DP Parts: Need for Postprocessing in 3DP, *Surface Treatment Methods:* Subtractive Machining Methods, Thermal-based Methods, Abrasive-based Methods, Chemical Methods. *Surface Protection, Functionalization, and Decorative Methods.* Heat Treatment and Aging. Establish a Relationship between Processing Parameters, Resulting Microstructure, Mechanical Properties, Fatigue, Creep and Corrosion Resistance of 3DP Parts. *Testing of 3DP Parts:* Metrology Measurement Methods, Porosity and Density, Dimensions, Mechanical Measurement Methods, NDT Methods of 3DP Parts, 3DP Safety, 3DP Standards.

Learning Resources:

Textbooks:

1. Mathematical Elements for Computer Graphics, David F. Rogers, J. A. Adams, Tata McGrawHill, 2008.
2. A Guide to Additive Manufacturing, Damir Godec, Joamin Gonzalez-Gutierrez, Axel
3. Nordin, Eujin Pei, Julia Urena Alcazar, Springer, 2022.
4. Additive Manufacturing Technologies, Ian Gibson, David Rosen, Brent Stucker, and Mahyar Khorasani, 3rd Edition, Springer, 2021.
5. A Practical Guide to Design for Additive Manufacturing, Diegel, Olaf, Axel Nordin, and Damien Motte, Springer, 2020.
6. Post-processing Techniques for Additive Manufacturing, Zafar Alam Faiz Iqbal, Dilshad Ahmad Khan, CRC Press, 2024.

References Books:

1. Geometric Modeling, Michael E.Mortenson, McGrawHill, 2013.
2. Rapid Prototyping: Laser-based and Other Technologies, Patri K. Venuvinod and Weiyin Ma, Springer, 2004.
3. Additive Manufacturing with Metals: Design, Processes, Materials, Quality Assurance, and Applications, Sanjay Joshi, Richard P. Martukanitz, Abdalla R. Nassar, Pan Michaleris, Springer, 2023.
4. Laser-Induced Materials and Processes for Rapid Prototyping, L.Lu, J. Y. H. Fuh and Y.S.Wong, Springer, 2001.
5. Rapid Prototyping: 3D Printing and Additive Manufacturing Principles & Applications, Chua Chee Kai, Leong Kah Fai, 5th Edition. World Scientific, 2019.
6. Handbook of Post-Processing in Additive Manufacturing: Requirements, Theories, and Methods, Gurminder Singh, Ranvijay Kumar, Kamalpreet Sandhu, Eujin Pei, and Sunpreet Singh, CRC Press, 2024.

ME36023 **3-0-0 (3)**

DATA SCIENCE IN MANUFACTURING

Pre-Requisites: **None**

Course Outcomes:

CO1	Explore the scope and prospects of data science in manufacturing
CO2	Evaluate the quality of data and perform appropriate data processing
CO3	Understand the different statistical tools that forms the base for machine learning
CO4	Learn machine learning concepts used in manufacturing processes
CO5	Develop innovative approaches to solve production related problems through data science

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Fundamentals of Analytics: Introduction to data-driven decision making; general introduction to data driven strategy and its importance; use of examples and mini-case studies to illustrate the role of statistical analysis in decision making. Types of data and data collection techniques.

Basic Data Analysis: Various types of data that are commonly collected by firms; methods to be used and inferences/insights that can be obtained depending on the type of data that are available (stated versus revealed preference, level of aggregation, cross- sectional, time series, panel data and so forth); use of frequency distributions, mean comparisons, and cross tabulation; statistical inferences (Hypothesis Testing) using chi- square test; t-test and ANOVA.

Introduction to Python for Data Science: Variables and Datatypes – Operators – Numpy – Pandas - Control structures & Functions - Data Visualization - Control structures – Case Studies

Machine Learning: Supervised ML models (Regression and Classification), Unsupervised ML models (Clustering) and Reinforcement Learning (Modern manufacturing use cases – Production Line Robots), Introduction to Computer Vision and Natural Language Processing

Data Science in Manufacturing: Data analysis in manufacturing and production planning processes (Material Planning, Demand Forecast and Production planning), Supply Chain Analytics - Informed decision making in production lines (Dashboards and KPIs), Predictive Maintenance and Defect detection of manufactured components using Machine vision, ultrasonic inspection, and deep learning.

Case Studies in Manufacturing: Case studies pertaining to data analysis in manufacturing– Demand Forecast and Production planning, Supply Chain Analytics - Predictive Modelling – Quality Control - Pricing etc.

Learning Resources:

Textbooks:

1. Data Analytics using Python, Bharti Motwani, Wiley 2020.
2. Data Science, John D. Kelleher, Brendan Tierney, MIT Press, 2018.

Reference Books:

1. Probability and Statistics in Engineering, William W. Hines, Douglas C. Montgomery, Wiley, 3rd Edition, 1990.
2. Essential Math for Data Science, Hadrien Jean. O Reilly 2020.
3. Practical Statistics for Data Scientists, Peter Bruce, Andrew Bruce and Peter Gedeck. O Reilly, 2020

ME36025 **3-0-0 (3)**

AUGMENTED REALITY AND VIRTUAL REALITY

Pre-Requisites: **None**

Course Outcomes:

CO1	Apply fundamental Computer Vision, Computer Graphics, and Human-Computer Interaction techniques to develop and enhance VR/AR applications effectively
CO2	Explore geometric modeling techniques, investigate virtual environments, and assess VR/AR technologies comprehensively
CO3	Utilize a variety of hardware devices and software in Virtual Reality systems to optimize functionality and performance.
CO4	Build Virtual/Augmented Reality applications by formulating creative design strategies.

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Introduction to Virtual Reality (VR)

Virtual Reality and Virtual Environment, Computer graphics, Real time computer graphics, Flight Simulation, Virtual environment requirement, benefits of virtual reality, Historical development of VR, Scientific Landmark

Computer Graphics and Geometric Modelling

The Virtual world space, positioning the virtual observer, the perspective projection, human vision, stereo perspective projection, Color theory, Conversion From 2D to 3D, 3D space curves, 3D boundary representation, Simple 3D modelling, 3D clipping, Illumination models, Reflection models, Shading algorithms, Geometrical Transformations: Introduction, Frames of reference Modelling transformations, Instances, Picking, Flying, Scaling the VE, Collision detection.

Virtual Environment

Input/Output Devices**:** Input (Tracker, Sensor, Digital Gloves, Movement Capture, Videobased Input, 3D Menus & 3D Scanner, etc.), Output (Visual/Auditory/Haptic Devices)

Generic VR system**:** Introduction, Virtual environment, Computer environment, VR technology, Model of interaction, VR Systems, Animating the Virtual Environment: Introduction, The dynamics of numbers, Linear and Nonlinear interpolation, the animation of objects, linear and non-linear translation, shape & object in between, free from deformation, particle system

Physical Simulation**:** Introduction, Objects falling in a gravitational field, Rotating wheels, Elastic collisions, projectiles, simple pendulum, springs, Flight dynamics of an aircraft.

Augmented Reality (AR)

Taxonomy, Technology and Features of Augmented Reality, AR Vs VR, Challenges with AR, AR systems and functionality, Augmented Reality Methods, Visualization Techniques for Augmented Reality, Enhancing interactivity in AR Environments, Evaluating AR systems.

Development Tools and Frameworks

Human factors: Introduction, the eye, the ear, the somatic senses. Hardware**:** Introduction, sensor hardware, Head-coupled displays, Acoustic hardware, Integrated VR systems Software: Introduction, Modelling virtual world, Physical simulation, VR toolkits, Introduction to VRML

AR / VR Applications

Introduction, Engineering, Entertainment, Science, Training, Game Development

Learning Resources:

Text Books:

1. Coiffet, P., Burdea, G. C., Virtual Reality Technology," Wiley-IEEE Press, 2003
2. Schmalstieg, D., Höllerer, T., "Augmented Reality: Principles & Practice," Pearson, 2016
3. Norman, K., Kirakowski, J., Wiley Handbook of Human Computer Interaction," Wiley-Blackwell, 2018

Reference Books:

1. Craig, A. B., Understanding Augmented Reality, Concepts and Applications," Morgan Kaufmann, 2013
2. Craig, A. B., Sherman, W. R., Will, J. D., Developing Virtual Reality Applications, Foundations of Effective Design," Morgan Kaufmann, 2009.
3. John Vince, J., "Virtual Reality Systems, Pearson, 2002
4. Sanni Siltanen, S., "Theory and applications of marker-based augmented reality," Julkaisija – Utgivare Publisher, 2012
5. Fowler, A., Beginning iOS AR Game Development: Developing Augmented Reality Apps with Unity and C#," Apress, 2019.

Online Resources:

1. Manivannan, M., (2018), "Virtual Reality Engineering," IIT Madras, https://nptel.ac.in/courses/121106013
2. Misra, S., (2019), "Industry 4.0: Augmented Reality and Virtual Reality," IIT Kharagpur, https://www.youtube.com/watch?v=zLMgdYI82IE
3. Dube, A., (2020), "Augmented Reality - Fundamentals and Development," NPTEL Special Lecture Series, https://www.youtube.com/watch?v=MGuSTAqlZ9Q
4. http://cambum.net/course-2.htm

ME36027 **3-0-0 (3)**

DESIGN FOR MANUFACTURABILITY

Pre-Requisites: **None**

Course Outcomes:

CO1	Understand the importance of DFM in the product development cycle.
CO2	Apply DFM principles to design products that are easy and cost-effective to manufacture.
CO3	Analyze the impact of material selection and manufacturing processes on product design.
CO4	Collaborate effectively with manufacturing teams to improve product manufacturability.
CO5	Evaluate and implement DFM tools and techniques in real-world scenarios.

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Introduction to DFM

Overview of DFM and its importance, History and evolution of DFM**,** The relationship between design and considerations for different manufacturing processes

Tolerancing and Geometric Dimensioning, Cost Analysis, and Reduction Techniques

Importance of tolerances in manufacturing**,** Geometric Dimensioning and Tolerancing (GD&T) basics**,** Tolerance analysis and stack-up**.**Cost components in manufacturing**,** Techniques for reducing manufacturing costs**,** Cost-benefit analysis of design changes

DFM Tools and Software

Overview of DFM tools and software applications, Hands-on sessions with DFM software, Integration of DFM tools in the design process

Design for Reliability and Quality: Ensuring product reliability through design, Quality control and assurance in manufacturing, Design for Six Sigma (DFSS) principles

Case Studies and Industry Examples and Collaborative Design manufacturing, Design Principles for Manufacturability: General design guidelines, Simplification of product design, Standardization and modularity, Design for assembly (DFA) principles.

Material Selection, Manufacturing Processes and Capabilities

Criteria for selecting materials, Impact of material properties on manufacturability, Case Studies on material selection.Overview of common manufacturing processes (e.g., machining, casting, molding, forming), Process capabilities and limitations, Design and Manufacturing

Real-world examples of successful DFM implementation, Analysis of DFM failures and lessons learned, Guest lectures from industry professionals, Importance of cross-functional teams, Techniques for effective communication between design and manufacturing teams, Concurrent engineering practices

Sustainability in DFM

Design considerations for sustainability, Impact of manufacturing processes on the environment, Life cycle assessment (LCA)

Advanced Topics in DFM

Emerging trends and technologies in DFM, Additive manufacturing and its impact on DFM, Digital manufacturing and Industry 4.0

Learning Resources:

Textbooks:

1. "Design for Manufacturability & Concurrent Engineering" by David M. Anderson
2. "Product Design for Manufacture and Assembly" by Geoffrey Boothroyd, Peter Dewhurst, and Winston Knight
3. "Manufacturing Processes for Design Professionals" by Rob Thompson

Additional Resources:

1. Journal articles and conference papers on DFM
2. Online tutorials and webinars
3. Industry standards and guidelines

ME36031 **3-0-0 (3)**

MATERIALS, ENERGY SOURCES AND BONDING MECHANISMS

Pre-Requisites: **None**

Course Outcomes:

CO1	Understand the essential properties and characteristics of Laser, Electron and Plasma energy sources.
CO2	Explore the energy sources on their functionality for industrial and medical applications.
CO3	Analyze the influence of process parameters on the energy-materials interaction.
CO4	Explore and evaluate non-conventional energy sources for manufacturing processes.

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Introduction, Energy Sources for Material Processing, and Classification of Energy Sources

Solidification Theory: Nucleation – Metals and Alloys – Melt Pool Dynamics – Morphology- Constitutional supercooling (Alloys) - Variables that controls melt-pool solidification behavior (growth rate, temperature gradient, melt pool shape, travel speed, undercooling, and alloy constitution)

Lasers in Manufacturing

Introduction -Laser cutting (machining)-Laser welding- Laser Bending or Forming - Laser surface treatment - Additive manufacturing

Electron Beam: Introduction, Wave Properties, and Characteristics - Constructive Interference and Destructive Interference; Generation of Electron Beam: Free Electrons, Cathode, Anode, Control Electrode, Focusing Lens, Deflecting System, Beam Correction System, and Vacuum.

Parameters: Accelerating Voltage, Power Density, Beam Current, Lens Current, Focal Position, Beam Speed, Beam Deflection; Process Related Effects: Liquid and Vapour Phases, Effect of Vacuum, Solidification, and Heat Affected Zone, Internal Thermal Stresses; Electron beam Interaction with different forms of Material; other Applications.

Electron Beam Technology: EBT in Additive Manufacturing- Powder Bed Fusion- Electron Beam Melting - Materials - Powder Metallurgy Requirements for EBM - Powder Manufacturing - Gas Atomization - Induction Plasma Atomization - Armstrong Process - Hydride-Dehydride - Characterization - Parameter Development - Build Setup and Process -Latest literature

Plasma Arc: Introduction, Basic Properties, Characteristics, and Types; Plasma Production; Parameters; Plasma with Various Forms of Material Interaction; Applications.

Other Sources: Ultrasonic, Hybrid etc.

Learning Resources:

Text Books:

1. Steen, W. M., Laser Material Processing, Springer-Verlag, London, 2005
2. Schultz H., Electron Beam welding, Woodhead Publishing, 1994

3. Lieberman M.A. and Lichtenberg A. J., Principles of Plasma Discharge and Materials Processing, Wiley Interscience, 1994.
4. Li Yang · Keng Hsu · Brian Baughman Donald Godfrey · Francisco Medina Mamballykalathil Menon · Soeren Wiener, Additive Manufacturing of Metals: The Technology, Materials, Design and Production, Springer, 2017.
5. Microstructure, Texture and Mechanical Property Evolution during Additive Manufacturing of Ti6Al4V Alloy for Aerospace Applications, Alphons Anandaraj ANTONYSAMY, Ph.D Thesis, University of Manchester.

ME36033 **3-0-0 (3)**

CIRCULAR ECONOMY

Pre-Requisites: **None**

Course Outcomes:

CO1	Apply the concept of circular economy to environmental engineering problems
CO2	Understand the concept of circularity and conduct relevant research
CO3	Use the principles of circularity for application to sustainable development
CO4	Apply complexity aspects of circular economy for creating circular business models

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Introduction: Linear Economy and its emergence, Economic and Ecological disadvantages of linear economy, Replacing Linear economy by Circular Economy, Development of Concept of Circular Economy, A differential - Linear Vs Circular Economy

Characteristics of Circular Economy: Material recovery, Waste Reduction, reducing negative externalities, Explaining Butterfly diagram, Concept of Loops

Circular design, innovation and Assessment: Zero waste: Waste Management in context of Circular Economy, Circular design, Research and innovation, LCA, Circular Business Models

Case Studies: Business models, Solid Waste Management / Wastewater, Plastics: A case study, EPR: polluters pay principle, Industrial symbiosis/ ECOparks

Legal and policy framework: Role of governments and networks, Sharing best practices, Universal circular economy policy goals, India and CE strategy, ESG

Learning Resources:

Text Books:

1. Walter R Stahel, The Circular Economy A User's Guide, Routledge, 2019, 1st Edition
2. Shalini Goyal Bhalla, Circular Economy: (Re) Emerging Movement, Invincible Publisher

Reference Books:

1. Peter Lacy, Jessica Long, Wesley Spindler, The Circular Economy Handbook: Realizing The Circular Advantage, Palgrave Macmillan UK
2. Peter Lacy, Jakob Rutqvist, Waste to Wealth: The Circular Economy Advantage, Palgrave Macmillan

Other Suggested Readings:

1. https://www.coursera.org/learn/circular-economy
2. https://www.edx.org/course/circular-economy-an-introduction
3. https://www.coursera.org/learn/sustainable-digital-innovation
4. https://online-learning.harvard.edu/course/introduction-circular-economy?delta=0

5. https://www.oecd.org/cfe/regionaldevelopment/Ekins-2019-Circular-Economy-WhatWhy-How-Where.pdf
6. https://ic-ce.com/product/principles-of-circular-economy/
7. https://ic-ce.com/product/circular-business-management/
8. https://ic-ce.com/product/bootcamp/
9. http://ic-ce.com/journal-on-circular-economy/

ME46033 **2-0-2 (3)**

Systems Thinking for Engineering Applications

Pre-Requisites: None — Basic engineering background is sufficient.

Course Outcomes:

CO1	Understand and explain the fundamental concepts of systems thinking — system boundaries, stocks, flows, feedback loops, delays, and non-linearity — in the context of mechanical engineering systems.
CO2	Construct and interpret Causal Loop Diagrams (CLDs) and Stock-and-Flow (SF) models to represent the dynamic behaviour of thermal, manufacturing, design, and automobile engineering systems.
CO3	Analyse system archetypes, feedback structures, and systemic failure modes to diagnose leverage points and unintended consequences in complex engineering problems.
CO4	Evaluate dynamic system behaviour including oscillations, overshoot, collapse, and growth using qualitative and introductory quantitative system dynamics modelling tools.
CO5	Design systemic interventions for complex real-world engineering problems by integrating systems thinking principles with sustainability, resilience, and sociotechnical considerations.

CO-PO Correlation Matrix

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Syllabus:

Foundations of Systems Thinking: Why reductionist thinking fails for complex engineering problems; what is a system; system boundary, elements, interconnections, and purpose; open vs closed systems; stocks and flows — the building blocks of dynamic systems; Little's Law; feedback loops — reinforcing and balancing; delays; non-linearity and limits to growth; system traps; mental models and bounded rationality; case studies.

System Archetypes and Feedback Dynamics: Introduction to system archetypes — eight classic patterns (Senge, 1990); Archetypes 1–4: Limits to Growth, Shifting the Burden, Fixes that Fail, Tragedy of the Commons; Archetypes 5–8: Escalation, Eroding Goals, Growth and Underinvestment, Accidental Adversaries; oscillation and instability in feedback systems; archetype case studies across ME domains.

Causal Loop Diagrams and Stock-Flow Modelling: CLD notation, polarity conventions, loop identification and labelling; CLD construction; Systems Mapping methods — participatory causal mapping; comparing and combining CLDs with other causal mapping approaches (Barbrook-Johnson and Penn, 2022); Stock-and-Flow diagram notation; constructing SF models; rate and level equations; introduction to Vensim PLE software; simulation of reference mode behaviour; model validation and testing; sensitivity analysis; group modelling exercise.

Systems Thinking in Mechanical Engineering Domains: Systems Thinking in Thermal Engineering — CLD and case study: combined cycle power plant; Systems Thinking in Manufacturing Engineering — production system as a stock-flow network; Systems Thinking in Design Engineering — product development rework loops and schedule dynamics; Systems Thinking in Automobile Engineering — vehicle programme delay; cross-domain integration.

Complexity, Leverage, Sustainability and Systemic Design: Leverage points — Meadows' 12 places to intervene in a system; Complex Adaptive Systems; resilience and sustainability through a systems lens; Sociotechnical systems and transition dynamics; systemic design methodology; capstone project reviews — systems model and intervention recommendation presentations.

Experiential Practice and Capstone Project Work:

Student teams construct a complete Causal Loop Diagram and Stock-and-Flow model for a real engineering problem from their specialisation, identify leverage points using Meadows' hierarchy, and present a systems-aware intervention recommendation with sustainability implications. Vensim PLE software is used for simulation.

Learning Resources:

Text Books :

1. Donella H. Meadows (Ed. Diana Wright), Thinking in Systems: A Primer, Chelsea Green Publishing, 2008.

2. John D. Sterman, Business Dynamics: Systems Thinking and Modeling for a Complex World, McGraw-Hill/Irwin, 2000.

Reference Books:

1. Peter M. Senge, The Fifth Discipline: The Art and Practice of the Learning Organization, Updated Edition, Doubleday/Currency, New York, 2006.

2. Pete Barbrook-Johnson and Alexandra S. Penn, Systems Mapping: How to Build and Use Causal Models of Systems, Palgrave Macmillan, 2022. [Open Access — full PDF freely available at link.springer.com]

3. Brian C. Dangerfield (Ed.), System Dynamics: Theory and Applications, Springer, New York, 2020.

4. David Peter Stroh, Systems Thinking for Social Change: A Practical Guide to Solving Complex Problems, Chelsea Green Publishing, 2015.

ME26022 **3-0-0 (3)**

DIGITAL TWIN IN MANUFACTURING

Prerequisite: NIL

Course Outcomes:

CO1	Understand the concept and significance of digital twins in manufacturing.
CO2	Learn the tools and technologies used in developing digital twins.
CO3	Explore the application of digital twins in various manufacturing processes.
CO4	Analyse case studies to understand real-world applications and benefits.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Detailed Syllabus

Introduction to Digital Twins and Architecture Overview of Digital Twins, Definition and history, Importance in manufacturing, Industry 4.0 and the role of digital twins

Data acquisition in digital Twin The Need for Electronics in Manufacturing, signal processing and importance of digital twin, Image Processing for Digital Twin: Image enhancement, segmentation and introduction to image processing in manufacturing.

Data communication in digital twin Overview, IoT and Network IoT Framework, Introduction to the Edge, Fog, and Cloud Computing, The Necessity of Cloud and Edge Computing in Industry, Real-Life Example in Manufacturing

Data-driven modelling and machine learning for digital twins Introduction to Artificial Intelligence, Requirement of Artificial Intelligence in a Digital Twin, Mathematical modelling, Physical and process modelling, Predictive maintenance, Real-time analytics

Digital Twin Application Digital Twins for Design and Manufacturing, Digital Twins for Service, Challenges and Intelligence, Real-Life Examples in Manufacturing

Learning Resources:

Text Books:

1. “Building Industrial Digital Twins Design, Develop, and Deploy Digital Twin Solutions for Real-world Industries Using Azure Digital Twins” Shyam Varan Nath, Pieter van Schalkwyk, Dan Isaacs Packet Publishing
2. “Digital twin driven smart design “ Tao F, Liu A, Hu T, Nee AY. Academic Press; 2020.

References

1. “Digital Twin Technology Fundamentals and Applications”, Manisha Vohra Wiley 2022
2. “Digital Twin – Fundamental, Concepts to Applications in Advanced Manufacturing” Surjya Kanta Pal, Debasish Mishra , Arpan Pal Samik Dutta, Debashish Chakravarty , Srikanta Pal Springer

Important links

1. https://www.csccm.in/courses/introduction-to-digital-twins

ME26026 **3-0-0 (3)**

ADVANCED COMPOSITE MATERIALS AND PROCESSING

Pre-requisites: NIL

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

CO1	Understand different types of composites and their applications.
CO2	Analyze various types of fabrication methods of polymer composites.
CO3	Describe the preparation of MMC's and their advanced fabrication procedures.
CO4	Select the best fabrication technique to fabricate a particular composite material and its post-processing techniques

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	1	2	1	1
CO-2	3	2	2	2	2	3
CO-3	2	3	3	2	1	3
CO-4	2	3	2	3	3	1
CO-5	3	3	2	1	1	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Syllabus:

INTRODUCTION TO COMPOSITES: Fundamentals Of Composites – Need for Composites – Enhancement of Properties – Classification of Composites – Matrix-Polymer Matrix Composites (PMC), Metal Matrix Composites (MMC), Ceramic Matrix Composites (CMC) – Reinforcement – Particle Reinforced Composites, Fibre Reinforced Composites. Applications of Various Types of Composites. Fibre Production Techniques for Glass, Carbon and Ceramic Fibers

Polymer Matrix Composites (PMC): Thermo set, thermoplastic and elastomeric polymers, their properties, characteristics and utilisation as matrices. PMC Processes – Hand Lay Up Processes – Spray Up Processes – Compression Moulding – Reinforced Reaction Injection Moulding – Resin Transfer Moulding – Pultrusion – Filament Winding – Injection Moulding. Fibre Reinforced Plastics (FRP), Glass Fibre Reinforced Plastics (GFRP). Laminates- Balanced Laminates, Symmetric Laminates, Angle Ply Laminates, Cross Ply Laminates. -Applications Of PMC In Aerospace, Automotive Industries. Their characteristic features, properties of composites made and their applications.

Metal Matrix Composites (MMC): Characteristics Of MMC, Metals, Inter-metallics and alloys used for MMC and their properties, Various Types of Metal Matrix Composites Alloy Vs. MMC, Advantages of MMC, Limitations of MMC, Reinforcements – Particles – Fibres. Effect of Reinforcement – Volume Fraction – Rule of Mixtures. Processing of MMC – Powder Metallurgy Process - Advanced Sintering mechanisms – Friction Stir Processing – Additive Manufacturing - Microwave Stir Casting – Squeeze Casting – Laser Cladding, A Spray Process, Liquid Infiltration In-Situ Reactions – Interface - Measurement of Interface Properties - Applications of MMC In Aerospace, Automotive Industries.

Ceramic Matrix Composites (CMC): Engineering Ceramic Materials – Properties – Advantages – Limitations, Need of CMC, Classification of ceramics and their potential role as matrix materials. Processing of CMC Chemical Vapor Infiltration (CVI), Precursor Infiltration and Pyrolysis (PIP), Sintering – Hot Pressing – Cold Isostatic Pressing (CIP) – Hot Isostatic Pressing (HIP) – Spark Plasma Sintering, Microwave Sintering, Additive Manufacturing (3D Printing). Carbon /Carbon Composites – Advantages of Carbon Matrix – Limitations of Carbon Matrix Carbon Fibre – Chemical Vapour Deposition of Carbon-On-Carbon Fibre Perform, Sol-Gel Processing.

Post-Processing Operations: Machining, cutting, polishing, welding of thermoplastic PMC, bonding, riveting and painting. Advanced post processing methods like ultrasonic welding, plasma coating, waterjet cutting and laser machining.

Learning Resources:

Textbooks:

1. Chawla. K.K., Composite Materials - Science and Engineering, Springer, 2001.
2. Jones, R.M., Mechanics of Composite Materials, Taylor and Francis, 1999.
3. Mathews F. L. And Rawlings R. D., “Composite Materials: Engineering and Science”, 1st Edition, Chapman and Hall, London, England,1994.
4. Materials Science and Engineering, An introduction. WD Callister, Jr., Adapted by R. Balasubramaniam, John Wiley & Sons, NY, Indian edition, 2007.

Reference Books:

1. Lubin, G., Handbook of Composites, Van Nostrand Reinhold Co., 1982.
2. Eckold, G., Design and Manufacture of Composite Structures, Wood head Publishing Ltd., 1994.
3. Clyne, T. W. And Withers, P. J., “Introduction To Metal Matrix Composites”, Cambridge University Press,1993.
4. Strong, A.B., “Fundamentals Of Composite Manufacturing”, SME,1989.
5. Sharma, S.C., “Composite Materials”, Narosa Publications,2000.
6. Broutman, L.J. And Krock,R.M., “ Modern Composite Materials”, Addison-Wesley,1967.
7. ASM Hand Book, “ Composites”, Vol.21, ASM International,2001

ME26028 **3-0-0 (3)**

DESIGN AND ANALYSIS OF EXPERIMENTS

Pre-requisites: NIL

Course Outcomes:

CO1	Identify objectives and key factors in designing experiments.
CO2	Develop appropriate experimental design to conduct experiments.
CO3	Analyse experimental data and draw valid conclusions.
CO4	Develop empirical models using experimental data to optimize process parameters.
CO5	Design robust products and processes using parameter design approach.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed 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:

Textbooks:

1. Design and Analysis of Experiments, Montgomery D. C., John Wiley & Sons, 2010, 7thEdition.
2. Taguchi Techniques for Quality Engineering, Ross P. J., McGraw-Hill, NY, 2008.
3. Quality Engineering using Robust Design, Madhav S. Phadke, Prentice Hall, 1989

Reference Books:

1. Product and Process Design for Quality, Economy and Reliability, Dukkipati, R V and Pradip K Ray, New Age International,2010, 1st Edn.

Online Resources:

1. http://reliawiki.org/index.php/Experiment_Design_and_Analysis_Reference
2. https://ieeexplore.ieee.org/abstract/document/6771276
3. https://link.springer.com/chapter/10.1007/978-1-4684-1472-1_1

ME26030 **3-0-0 (3)**

PRODUCT LIFE CYCLE MANAGEMENT

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Course Articulation Matrix:

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

Detailed Detailed Syllabus:

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

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

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

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

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

Implementing end to end business process management: Product lifecycle management as a business strategy tool, Product lifecycle management as an enabler of cooperation between companies, Contents of collaboration, Successful cooperation, Tools of collaboration, From changes in the business environment to product strategy, Business Benefits of PLM.

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

Case Studies with Siemens Teamcenter PLM or similar softwares.

Learning Resources:

Textbooks:

1. John Stark, Product Lifecycle Management (Volume 1): 21st Century Paradigm for Product Realisation (Decision Engineering), Springer, 2020.
2. Antti Saaksvuori, Anselmi Immonen , Product Lifecycle Management, Third Edition, Springer, 2008.
3. *SOA approach to Enterprise Integration for Product Lifecycle*, IBM Red books, 2011.
4. Udhayan Elongovan, Product Life Cycle Management (PLM), A Digital Journey using Industrial Internet of Things, 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, 5thEdition, Pearson, 2019.

ME26032 **3-0-0 (3)**

RAPID TOOLING AND INDUSTRIAL APPLICATIONS

Pre-Requisites: Nil

Course Outcomes:

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

CO1	Understand the working principle and process parameters of rapid tooling methods
CO2	Develop appropriate rapid tools for any given aerospace application
CO3	Design and fabricate customized implants for the given medical application
CO4	Select appropriate rapid tools for any given automobile application
CO5	Identify suitable tooling methods for any given industrial application

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

DETAILED DETAILED SYLLABUS:

Rapid Prototyping and Tooling: Properties of Prototyping, Characteristics of Rapid Prototyping, Strategic Aspects for the use of Prototypes, Operational Aspects in the use of Prototypes, Applications of Rapid Prototyping in Industrial Product Development with Examples. Conventional Tooling Vs. Rapid Tooling.

Indirect Methods for Rapid Tool Production: Classification of Rapid Tooling Methods. Role of Indirect Methods in Tool Production. Metal Deposition Tools, RTV Tools, Epoxy Tools, Ceramic Tools, Cast Metal Tools, Investment Casting, Fusible Metallic Core, Sand Casting, Keltool™ Process. Case Studies.

Direct Methods for Rapid Tool Production: Classification of Direct Rapid Tool Methods. Direct ACES™ Injection Moulds (AIM™), Laminated Object Manufactured (LOM) Tools, DTM RapidTool™ Process: RapidSteel 1.0, RapidSteel 2.0, Copper Polyamide (PA). SandForm™, EOS DirectTool™ Process, Direct Metal Tooling using 3DP™, Topographic Shape Formation (TSF). Case Studies.

Aerospace and Defence Industry: An Overview of AM Applications, AM as a Complete Value Chain. Aerospace Materials and their Requirements, Review of AM Technologies for the Aerospace Industry, Qualification and Certification of AM Parts, Design Considerations, Measurement of Feedstock Material Characteristics and Quality for Aerospace Alloys, The Processing and Heat Treatment of Super Alloys, Testing of Mechanical Properties, Surface Roughness and Fatigue Properties of Aero Parts, Non-destructive Evaluation of AM Parts, Aerospace Case Studies.

Medical and Dental Industry: 3D Data Capture and Medical Scanning Technologies, Medical Image Processing Software Systems, Biomaterials, Virtual and Diagnostic Models, Planning and Simulation of Complex Surgeries, Design and Fabrication of Customized Implants and Prosthesis, Design and Production of Medical Devices, Tissue Engineering and Organ Printing, Medical Case Studies.

Automotive Industry: Multi-material Manufacturing and prototyping, Making Cars with Ergonomic Hand-held Tools, Jigs and Fixtures, Components of Electric Vehicles, Formula 1, Cooling Ducts, Intake Manifolds, Automobile Case Studies.

Other Industrial Applications of AM: Marine, Railway, Oil and Gas, Construction, Retail Industry, Arts and Architecture, Fashion and Textile, Jewellery Industry, Cion and Tableware, Weapons, Food, Packaging, and Toy Industry.

Learning Resources:

Textbooks:

1. Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping & Rapid Tooling, D.T. Pham and S.S Dimov, Springer, 2001.
2. A Guide to Additive Manufacturing, Damir Godec, Joamin Gonzalez-Gutierrez, Axel Nordin, Eujin Pei, Julia Urena Alcazar, Springer, 2022.
3. Additive Manufacturing for the Aerospace Industry, Francis Froes, Rodney Boyer, Elsevier, 2019.
4. Rapid Prototyping: 3D Printing and Additive Manufacturing Principles & Applications, Chua Chee Kai, Leong Kah Fai, 5th Edition. World Scientific, 2019.
5. Medical Modelling: The Application of Advanced Design and Rapid Prototyping Techniques in Medicine, Richard Bibb, Dominic Eggbeer and Abby Paterson, Woodhead, 2017.
6. Advanced Manufacturing Technology for Medical Applications, Ian Gibson, John Wiley, 2006.

Reference Books:

1. Additive Manufacturing: 3D Printing for Prototyping and Manufacturing, Andreas ebhardt, Jan-Steffen Hötter, Hanser, 2016.
2. Rapid Prototyping, Tooling, and Manufacturing, A E W Rennie, C E Booking, D M Jacobson, Professional Engineering, 2002.
3. Rapid Tooling Technologies and Industrial Applications, Peter Hilton and Paul F Jacobs, Marcel Dekker Inc, New York, 2001.
4. Rapid Tooling Guidelines for Sand Casting, Wanlong Wang, Henry W. Stoll and James G. Conley, Springer, 2010.
5. 3D Printing in Medicine: A Practical Guide for Medical Professionals, Frak J. Rybicki, Gerald T. Grant, Springer, 2017.
6. Laser Additive Manufacturing: Materials, Design, Technologies, and Applications, Milan Brandt, Elsevier, 2017.

ME26034 **3-0-0 (3)**

SUSTAINABLE MANUFACTURING

Pre Requisites: None

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

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Detailed 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 an 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 – Discussthe 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.

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, Case Studies :Green packaging and supply chain, implementation of lean manufacturing at industries

Learning Resources:

Textbooks:

1. Montgomery Douglas, 2017. Design of Experiments, John Wiley and Sons, Inc.
2. Dornfeld, D.A. ed., 2012. Green manufacturing: fundamentals and applications. Springer Science & Business Media.
3. Ashby, M. F. Materials and the environment: eco-informed material choice. Elsevier, 2012.
4. Klemes, J., 2011. Sustainability in the process industry. McGraw-Hill. 2011
5. M.Karpagam, Geetha Jaikumar,Green Management, Ane Books Pvt.Ltd. 2010
6. M.K. Ghosh Roy, Design for Environment: A guide to sustainable Product Development Sustainable Development, Ane Books Pvt.Ltd,2009
7. G. Atkinson, S. Dietz, E. Neumayer, Handbook of Sustainable Manufacturing. Edward Elgar Publishing Limited, 2007

ME26036 **3-0-0 (3)**

COMPUTER CONTROL OF MANUFACTURING SYSTEMS

Pre-requisites: NIL

Course Outcomes:

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

CO1	Explain the principles and components of NC/CNC manufacturing systems.
CO2	Analyze NC/CNC machine tools, control loops, drives, feedback devices, and interpolation
CO3	Apply CNC programming and control methods for machining operations.
CO4	Evaluate adaptive control strategies to improve machining accuracy and productivity.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Syllabus

Introduction: Basic concepts in manufacturing systems, Fundamentals of Numerical Control, Advantages of NC systems, Classification of NC Systems

Features of NC Machine tools: Fundamentals of Machining, Design considerations of NC Machine tools, Methods of improving Machine Accuracy, Increasing Productivity with NC Machines, Machining Centers, MCU Functions

System Devices: Drives, Feedback devices, Counting Devices, Digital-to-Analog converters

Interpolators for Manufacturing Systems: DDA Integrator, DDA Hardware Interpolator, CNC Software Interpolator, Software DDA Interpolator, Reference-Word CNC Interpolators

Control Loops of NC Systems: Introduction, Control of point-to-point Systems, Control Loops in Contouring Systems

Computerized Numerical Control: CNC Concepts, Advantages of CNC, The Digital Computer, The Reference-Pulse Technique, Sampled-Data Technique, Microcomputers in CNC

Adaptive Control Systems: Introduction, Adaptive Control with Optimization, Adaptive Control with Constraints, Variable-Gain AC Systems, Adaptive Control of Grinding, Cost Analysis in Machining

Learning Resources

Text Books

1. Computer Numerical Control: Machining and Turning Centers, Michael J. Peterson, Pearson, 2003.
2. CNC Programming Handbook, Peter Smid, Industrial Press, 2003.
3. Numerical Control and Computer-Aided Manufacturing, T.K. Kundra, P.N. Rao, and N.K. Tewari, Tata McGraw-Hill Education, 1993.
4. Computer Numerical Control: Operation and Programming, Warren S. Seames, Prentice Hall, 2002.Automation, Production Systems, and Computer-Integrated Manufacturing, Mikell P. Groover, Pearson, 2014.
5. CNC Machines, B.S. Pabla and M. Adithan, New Age International, 2014.
6. Principles of Computer-Integrated Manufacturing, S. Kant Vajpayee, Prentice Hall, 1995.
7. Mechatronics: Principles and Applications, Godfrey C. Onwubolu, Butterworth-Heinemann, 2005.
8. Computer Control of Manufacturing Systems, Yoram Koren, McGraw-Hill, 1983.

ME26038 **3-0-0 (3)**

FLEXIBLE MANUFACTURING SYSTEMS

Pre-requisites: None
Course Outcomes: At the end of the course, the student shall be able to:

CO1	Classify and distinguish FMS and other manufacturing systems including job-shop and mass production systems.
CO2	Explain processing stations and material handling systems used in FMS environments.
CO3	Design and analyze FMS using simulation and analytical techniques.
CO4	Describe tool management in FMS.
CO5	Analyze the production management problems in planning, loading, scheduling, routing and breakdown in a typical FMS.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

DETAILED DETAILED SYLLABUS:

Understanding of FMS: Evolution of Manufacturing Systems, FMS: Definition, objective and Need, FMS: components, Merits, Demerits and Applications, Flexibility in Pull and Push type.

Classification of FMS Layout: FMS: Layouts and their Salient features, Single line, dual line, loop, ladder, robot centre type etc.

Salient features of processing stations: Processing stations- Machining Centers, Turning centre, Coordinate measuring machine (CMM), Washing/ Deburring station.

MHS; An introduction: Material Handling System Conveyor, Robots, Automated Guided Vehicle (AGV), Automated Storage Retrieval System (ASRS).

Management Technology: Tool Management, tool magazine, Tool preset, identification, Tool monitoring and fault detection, FMS: Configuration planning and routing, FMS: Production Planning and Control, FMS: Scheduling and loading.

Design of FMS: FMS: Performance Evaluation introduction, Analytical model of FMS, Simulation model of FMS.

Case studies: Typical examples /case studies of FMS.

Learning Resources

Text Books

1. William W Luggen, “Flexible Manufacturing Cells and System” Prentice Hall of Inc New Jersey, 1991
2. Reza A Maleki “Flexible Manufacturing system” Prentice Hall of Inc New Jersey, 2012
3. "Manufacturing Systems Engineering" by Katsundo Hitomi. 2nd Edition (2017)
4. Groover,M.P “Automation, Production Systems and Computer Integrated Manufacturing”, Prentice Hall of India Pvt.Ltd. New Delhi 2016

ME26040 **3-0-0 (3)**

Reliability Engineering

Prerequisites: Nil

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	3	2	
CO4	3	2	2	2		
CO5	2	2	2	2	2	

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Detailed Syllabus:

Introduction: Probabilistic reliability, failures and failure modes, repairable and nonrepairable 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.

Learning Resources

Text Books

1. Ebeling CE, *An Introduction to Reliability and Maintainability Engineering*, TMH, New Delhi, 2004.

2. O'Connor P and Kleymer A, *Practical Reliability Engineering*, Wiley, 2012.

ME26042 **3-0-0 (3)**

ADVANCED MACHINING PROCESSES

Pre-Requisites: ME2601, ME2605

Course Outcomes:

CO1	Describe advanced machining processes
CO2	Analyze chemical and electrochemical processes
CO3	Classify hybrid electro chemical processes
CO4	Explain the material removal mechanism by thermal processes
CO5	Discuss the importance of material addition processes

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Syllabus:

Introduction: History of machining, traditional machining processes, nontraditional machining processes, hybrid machining processes. need for non-traditional machining processes. Mechanical Processes: Ultrasonic machining (USM): machining system, material removal process, factors affecting material removal rate, dimensional accuracy, and surface quality, applications. Water jet machining (WJM): machining system, process parameters, applications, advantages and disadvantages of WJM. Abrasive jet machining (AJM): machining system, material removal rate, applications, advantages and limitations of AJM. Hybrid Abrasive Flow Machining, Magnetic Abrasive Finishing.

Chemical Processes: Chemical Milling (CHM): tooling for CHM, process parameters, material removal rate, accuracy and surface finish, advantages, limitations, applications. Photochemical milling: process description, applications, advantages. Electro polishing: process parameters, applications, process limitations. Electrochemical Processes: Electrochemical machining (ECM): principles of electrochemical machining, ECM equipment, basic working principles, process characteristics, process control, applications. Chemo Magnetic Abrasive Finishing

Hybrid Electrochemical Processes: Electrochemical grinding (ECG): material removal rate, accuracy and surface quality, applications, advantages and disadvantages. Electrochemical honing: process characteristics, applications. Electrochemical super finishing: material removal process, process accuracy; Electrochemical buffing - material removal process, Electro chemical deburring.

Thermal Processes: Electric discharge machining (EDM): mechanism of material removal, machining system, material removal rates, heat-affected zone, applications. Wire EDM- principle, process parameters, surface finish and machining accuracy, applications. Laser beam machining (LBM): material removal mechanism, applications, advantages and limitations. Electron beam machining (EBM): basic equipment and removal mechanism, applications, advantages and disadvantages. Plasma beam machining (PBM): Microwave drilling machining systems, material removal rate, accuracy and surface quality, applications, advantages and disadvantages.

Material Addition Processes: Introduction, classification. Liquid-based techniques: stereolithography, holographic interference solidification, beam interference solidification, solid ground curing, liquid thermal polymerization, fused deposition modelling, multi jet modelling, ballistic particles manufacturing, shape deposition manufacturing. Powder-based processes: selective laser sintering, Friction Surfacing. Microwave

sintering, Microwave Cladding, laser engineered net shaping, three-dimensional printing. Solid-Based techniques -solid foil polymerization, laminated object modeling.

Learning Resources

Text Books:

5. El-Hofy, Hassan Abdel-Gawad, Advanced Machining Processes: Nontraditional and Hybrid Machining Processes, McGraw-Hill, 2005.
6. V.K. Jain, Advanced Machining Processes, 12th reprint, Allied Publishers Ltd, 2010.

Reference Books:

1. Pandey P.C. and Shah H.S, Modern Machining Processes, 1st Edition, TMH, 2010.
2. S. Kalpakjain and S. R.Schmid, Manufacturing Engineering and Technology, 7th Edition, Pearson, 2018.
3. Amitabha Bhattacharyya, New technology, Institution of Engineers, 1973

ME26044 **3-0-0 (3)**

LASERS IN MANUFACTURING TECHNOLOGY

Pre-Requisites: **Nil**

Course Outcomes:

CO1	Understand the essential characteristics of lasing materials and principles of lasers.
CO2	Identify the high-power lasers based on their functionality for different applications material processing.
CO3	Determine the requirement of laser components in different configurations.
CO4	Understand the applications of lasers for Selective Laser Sintering (SLS) Additive Manufacturing Technology

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	–	1	–	–
CO-2	2	1	–	1	–	1
CO-3	1	2	1	2	2	2
CO-4	2	1	1	1	–	–
CO-5	2	1	–	1	–	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Introduction to lasing action: Electromagnetic Radiation, Energy Levels, Interaction of Radiation and Matter, Spontaneous and stimulated emission, Population Inversion.

Properties of Laser Light: Line width, Beam Divergence Angle, Spatial Profiles of Laser Beams, Temporal Behaviour of Laser Output, Focusing Properties of Laser Radiation, Power.

Lasers Optics: Gas Lasers – He-Ne lasers, CO_2 Lasers, Excimer lasers; Solid state lasers. Semi-conductor diode lasers, High power diode lasers, optically pumped lasers, Diode-Pumped Solid State Tunable Lasers. Optical Cavity and design.

Laser components and configurations for different applications: Light beam deflectors, Q-switches, Beam profilers, Di-choric mirrors, polarizers

Interaction of High-Power Laser: Radiation with Materials, Laser Applications in Material Processing: welding, Hardening, Laser alloying, cladding, Laser induced material removal: drilling, cutting, marking

Applications of lasers: Selective Laser Sintering (SLS), Laser Direct Energy Deposition, Laser induced breakdown spectroscopy (LIBS), Welding and Forming Technologies, Lasers in metrology

Learning Resources:

Text Books:

1. Lasers: Fundamentals and applications, K. Thyagarajan, Ajoy Ghatak, Springer, 2010, 2nd Edition.

2. Industrial applications of Lasers, Ready, J.F, Academic Press, 1997, 2nd Edition.
3. Laser Fundamentals, Willium T Selfvast, Cambridge Univ. Press, 2008

Reference Books:

1. Selective Laser Sintering Additive Manufacturing Technology, Chunze Yan et al, Elsevier, 2020.
2. Lasers In 3D Printing and Manufacturing, Chee Kai Chua, Murukeshan Vadakke Matham, Young-jin Kim, World Scientific press, 2016.
3. Laser Additive Manufacturing: Materials, Design, Technologies, and Applications, Milan Brandt, Woodhead Publishing Series-Elsevier, 2016, 1st Edition.

Online Resource:

- https://nptel.ac.in/noc/courses/noc19/SEM1/noc19-cy13/
- https://stfc.ukri.org/research/lasers-and-plasma-physics/lasers-and-stfc/lasers-and-manufacturing/
- https://ocw.mit.edu/resources/res-6-005-understanding-lasers-and-fiberoptics-spring-2008/laser-fundamentals-i/
- https://www.asme.org/topics-resources/content/7-top-applications-of-lasers-in-manufacturing

ME16026 **3-0-0 (3)**

ADVANCED COMPUTATIONAL FLUID DYNAMICS

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed 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:

Textbooks:

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

Reference Books:

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

Online Resources:

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

ME46028 **3-0-0 (3)**

OPTIMIZATION METHODS FOR ENGINEERING DESIGN

Pre-Requisites: **None**

Course Outcomes:

CO-1	Formulate a design task as an optimization problem.
CO-2	Solve unconstrained optimization problems using corresponding methods.
CO-3	Solve unconstrained optimization problems using corresponding methods.
CO-4	Solve the nonlinear optimization problems with evolutionary methods

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	3	1	2
CO-2	2	2	3	3	2	2
CO-3	3		3	3	3	2
CO-4	3		3	3	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed 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 Unconstrained 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 and gradient based methods for constrained optimization. Formulation and Case studies.

Evolutionary Optimization algorithms: Philosophy**,** Genetic algorithms and simulated annealing.

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:

Text Books:

1. Jasbir Arora, Introduction to Optimum Design, Academic Press, 2004.

Reference Books:

1. Kalyanmoy Deb, Optimization For Engineering Design: Algorithms and Examples, PHI, 2004.
2. Kalyanmoy Deb, Multi-Objective Optimization using Evolutionary Algorithms, Wiley, 2001

ME46036 **3-0-0 (3)**

CHARACTERIZATION OF ENGINEERING MATERIALS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify advanced techniques available for characterization of materials
CO-2	Select a characterization technique to evaluate the behavior of materials
CO-3	Analyze defects and failure surfaces of materials
CO-4	Analyze the characterization results by various equipment

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	2	3	3
CO-2	3	2	2	2	2	2
CO-3	3	3		3		2
CO-4	3	3	2	2	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Introduction: Overview of the course; materials classification and their properties, Importance of materials selection, property classification, Criteria for selection of materials, Ashby charts for materials selection, Engineering Design process and the role of materials; material property charts; selection of materials based on function, objective, constraints and free variables; examples of material selection for typical applications.

Computer aided materials selection: Selection of process based on material classification; pencil curve approach; material selection for multiple constraints and multiple objective cases; multiple constraints and conflicting objectives. Co-selection of material and shape; concept of macroscopic and microscopic shape factors; Four quadrant method of material selection. General Properties of plastics, polymers and elastomers; visco-elastic properties; short-term and long-term properties of plastics.

High temperature materials: families of super alloys and their characteristics; creep and fatigue resistance of super alloys; role of precipitates in strengthening of super alloys; repair of super alloys after creep damage; coatings for high temperature materials.

Fundamentals of ceramics: general properties, applications of ceramics for critical applications. Design considerations. Surface treatment of materials using coatings; type of coatings; PVD and CVD coatings. Basics of electro-plating and electro-less plating.

Physical characterization of materials: Optical Microscopy, SEM,TEM, Density, Void content in materials, Electron Probe Micro Analyzer (EPMA), Atomic Force Microscopy (AFM), Thermogravimetric analysis (TGA), nano indentation, NMR spectroscopy, EDAX, FTIR, XRD

Mechanical characterization: Tensile test, flexural test, compression test, ILSS, creep, fatigue, Hardness, Impact test, Fracture toughness test, Principle, construction and operation working parameters, equipment operation. selection of plastics based on mechanical properties, degradation due to environment, of laminates.

Tribological characterization: Abrasive wear, Pin-on Disc, Erosion test, Corrosion test, sand abrasion, slurry erosion, scratch test, nano indent scratch test, wear; Design methods for snap fits; case studies. Fundamentals of fiber reinforced plastics; Stress, strain analysis of continuous fiber composites, rule of mixtures, general deformation behavior

Learning Resources:

Text Books:

1. M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Heinemann, 2010, 4th edition.
2. Yang Leng, Materials Characterization-Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia) Pte Ltd, 2008.
3. Dieter,George E, Mechanical Metallurgy, McGraw Hill, 2nd Edition, 2005

Reference Books:

1. ASM Handbook: Materials Characterization, ASM International, 2008.
2. V. T. Cherapin and A. K. Mallik, Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.
3. Crawford, R. J., Plastics Engineering, Butterworth-Heinemann, 3/e, 2002.
4. Donachie, M. J. and Donachie, S. J., Super alloys: A technical guide, ASM International, 2002.

Other Suggested Readings:

ME46030 **3-0-0 (3)**

ROBOTICS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify robots based on joints and arm configurations.
CO-2	Design application specific End Effectors for robots.
CO-3	Compute forward and inverse kinematics of robots and determine trajectory plan.
CO-4	Program robot to perform typical tasks including Pick and Place, Stacking and Welding
CO-5	Design and select robots for Industrial and Non-Industrial applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1			2	2	3	2
CO-2	2		3	2	3	2
CO-3	2		2	2	2	2
CO-4	2		2	2	2	2
CO-5	3	1	3	3	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed 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:

Text Books:

1. Fu, K.S., Gonzalez, R.C., and Lee, C.S.G., Robotics control, Sensing, Vision and Intelligence, McGraw-Hill Publishing company, New Delhi, 2003.

Reference Books:

1. Klafter, R.D., Chmielewski, T.A., and Negin. M, Robot Engineering: An Integrated Approach, Prentice Hall of India, New Delhi, 2002.
2. Craig, J.J., Introduction to Robotics Mechanics and Control, Addison Wesley,1999.
3. Kevin M. Lynch, Frank C. Park, Modern Robotics: Mechanics, Planning, and Control, Cambridge University Press, 2017

ME46038 **3-0-0 (3)**

SMART MATERIALS AND SENSORS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify smart materials based on the engineering applications
CO-2	Develop constitutive equations and mathematical models for the smart materials
CO-3	Design sensing devices and structures using smart materials
CO-4	Adapt smart sensors for measurement of physical properties and structural health monitoring

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2		3			
CO-2	3	2	3	2	3	2
CO-3	3	2	3	2	3	
CO-4	3	2	3	2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Introduction: Introduction of smart materials- Piezoelectric materials, magneto-strictive materials and magneto-resistance effect, electroactive materials and polymers, Shape memory alloys and polymers, electro and magneto rheological fluids, intelligent materials.

Piezoelectric Materials: Piezoelectric effect, Constitutive equations, properties of piezoelectric materials, variation of coupling coefficients for PZT materials, Mathematical modelling- Electro mechanical performance.

Magneto-strictive Materials and Shape memory alloys: Magneto-strictive Sensing Magneto mechanical coupling coefficients of magneto-strictive materials, constitutive relationships, Villari Effect, Matteuci Effect and Nagoka-Honda Effect, Magnetic Delay Line Sensing, Magneto strictive mini actuators. Classification of shape memory alloys, methods of fabrication, Control design for shape memory alloys and polymers, Electroactive polymers and its applications, LBHS and HBLS smart actuators.

Smart sensors: Selection of sensors and its monitoring techniques for monitoring force, position, vibration, noise, temperature for the mechanical systems-Integrated and distributed temperature sensing, strain measurements, fluid rheological properties measurements using FBG and ultrasonic sensors, Application of accelerometers, EAP, SMAs, vision sensors, MEMS based actuators, robot sensors, micro sensors, Nano sensors, Case studies and student presentations

Structural Health Monitoring using Smart Sensors: Structural integrity using fiber optic, acoustic/ultrasonic, and piezoelectric active sensors/patches, piezoelectric smart structures- numerical and experimental methods. Delamination sensing using magneto-strictive and Piezoelectric sensors. Case studies and student presentations.

Learning Resources:

Text Books:

1. Victor Giurgiutiu, Structural Health monitoring with Piezoelectric Wafer Active sensors, Academic Press, 2008, 1st edition
2. Thompson and Gandhi, Smart Materials and Structures, Chapman and Hall, 1992

Reference Books:

1. Alper Erturk and Daniel J Inmann, Piezoelectric energy harvesting, Wiley Publications, 2011, 1st edition
2. Krzysztof Iniewski, Smart sensors for industrial applications, CRC Press Taylor and Francis group, 2013.
3. Ananthasuresh, G. K., Vinoy, K. J., Gopalakrishnan, S., Bhat, K. N., and Aatre, V. K, Micro and Smart Systems: Technology and Modeling, Wiley, New York, 2012.

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/104/112104173/

ME36032 **3-0-0 (3)**

Artificial Intelligence and Machine Learning for Mechanical Systems

Pre-Requisites: **None**

Course Outcomes:

CO1	Understand the core concepts of Mechanical Systems in the context of Industry 4.o
CO2	Apply AI, ML and Deep Learning concepts on Various Mechanical Systems
CO3	Apply the statistical and optimization techniques on Mechanical Systems
CO4	Evaluate the Mechanical System performance using simulation and experimental analysis

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

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

Introduction of Statistics; Descriptive statistics: Central tendency measures, Dispersion measures, data distributions, center 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.

ME26048 **3-0-0 (3)**

IIoT and Haptics

Pre-requisites: Nil

Course outcomes:

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

CO1	Design, integrate, optimize mechatronic devices, and implement control systems for automation solutions
CO2	Select sensors/actuators, program, simulate, and innovate for addressing automation challenges effectively
CO3	Explore IIoT protocols, build simple IIoT systems with Arduino, ESP32, and Raspberry Pi for practical application
CO4	Development of Haptic devices for the automation systems

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Syllabus:

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 & Cloud Application Development: Solution framework for IoT applications- Implementation of Device integration, Data acquisition and integration, Cloud service and platforms: Commercial clouds (such as Amazon elastic compute cloud, Google Compute engine, Windows Azure), Storage services, database services, application services, content delivery services, analytics services. Case Studies: IIoT & Cloud based case studies and mini projects based on Industrial automation, Transportation, Agriculture, Healthcare, Home Automation.

Haptic Technology: Introduction to haptic systems and their applications, Generating haptic-feedback with a manipulator, Generating haptic-feedback with a manipulator, Introduction to haptic rendering, Real-time programming for generating force-feedback, Introduction to force-feedback telemanipulation, Haptic rendering of rigid bodies (collision detection), Haptic rendering of rigid bodies (force shading, friction rendering and texture rendering), Stability of haptic systems.

Learning Resources:

Text Books:

1. Vijay Madisetti, Arshdeep Bahga, A Hands on Approach", Internet of Things, University Press, 2020.

2. Troy McDaniel and Sethuraman Panchanathan, Haptic Interfaces for Accessibility, Health, and Enhanced Quality of Life, Springer, 2020.

Reference Books:

1. The Internet of Things: Enabling Technologies, Platforms, and Use Cases", Pethuru Raj and Anupama C. Raman, CRC Press, 2012
2. Designing the Internet of Things", Adrian McEwen, Wiley, 2015

Online :

1. https://ioe.iitm.ac.in/project/virtual-reality-and-haptics/
2. http://video_demos.colostate.edu/mechatronics

ME36036 **3-0-0 (3)**

SOFT COMPUTING TECHNIQUES

Pre-Requisites: **None**

Course Outcomes:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed 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.
2. https://www.iitk.ac.in/kangal/index.shtml

ME36022 **3-0-0 (3)**

SUPPLY CHAIN MANAGEMENT

Pre-Requisites: **None**

Course Outcomes:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed 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/

ME36024 **3-0-0 (3)**

MODELLING AND SIMULATION OF MANUFACTURING SYSTEMS

Pre-Requisites: **None**

Course Outcomes:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed 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: 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.

ME36026 **3-0-0 (3)**

PROJECT MANAGEMENT

Pre-Requisites: **None**

Course Outcomes:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

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

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

Financial Analysis: Financial Estimates and Projections, Investment Criteria, Financing ofProjects.

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

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

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

Learning Resources:

Text Books:

1. Project: A Planning Analysis, Prasanna Chandra, Tata McGraw Hill Book Company,New Delhi, 2009, 4th Edition.
2. Project Management, Cleland, Gray and Laudon,Tata McGraw Hill Book Company,New Delhi, 2007, 3rd Edition.
3. Project Management - A Managerial Approach, Jack R. Meredith and Samuel J., Jr.Mantel, John Wiley, 2011, 6th Edition.

Reference Books:

1. The Critical Chain, Eliyahu M Goldratt, Business novel, 1997
2. A guide to the Project Management Body of Knowledge, Fourth Edition, Project

Management Institute, 2008

Online Resources:

1. https://www.pmi.org/
2. https://www.pma-india.org/pma-cert/

ME36028 **3-0-0 (3)**

MATERIALS AND PROCESS SELECTION FOR DESIGN

Pre-Requisites: **None**

Course Outcomes:

CO1	Select materials as per the design requirements of a given product.
CO2	Analyse the selection strategy and attribute limits for selecting appropriateprocesses
CO3	Develop the shape factors for structural sections
CO4	Design and develop hybrid materials to create product personality

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Introduction: The families of Engineering materials, The Design process, types of design, Design tools and materials data.

Materials Selection-The basics and case studies: Introduction and synopsis, the selection strategy, attribute limits and material indices, the selection procedure, computer- aided selection, the structural index, summary and conclusions, case studies

Selection of material and shape, case studies: Introduction and synopsis, shape factors, Microscopic or micro-structural shape factors, limits to shape efficiency, exploring and comparing structural sections, material indices that include shape, COselecting material and shape, summary and conclusions, case studies

Selecting candidate processes: A strategic view, selecting candidate processes, processinformation maps, Prima selection strategies, Prima categories: Casting, forming, machining processes.

Designing Hybrid materials and case studies: Introduction and synopsis, filling holesin material property space, hybrids of type 1, 2, 3, 4, Summary and conclusions, case studies

Information and knowledge sources for design: Introduction and synopsis, Information for materials and processes, screening information, supporting information, waysof checking and estimating data, Summary and conclusions

Materials and industrial design: Introduction and synopsis, the requirements pyramid, product character, using materials and processes to create product personality - Summary and conclusions.

Learning Resources:

Text Books:

1. Engineering Materials, M.F. Ashby: 4th Edition, Elsevier, 2005.
2. Materials Selection in Mechanical Design, M.F. Ashby: Butterworth Heinemann, 2005.
3. Materials Selection and Design, ASM Publication, Vol.20: ASM, 1997.
4. The Principles of Materials Selection and Design, Prentice Hall International, Pat L.

Mangonon: Inc.1999.

Reference Books:

1. Process selection from Design to Manufacture, K.G.Swift and J.D.Booker, BH Publication, 1997.

ME36038 **3-0-0 (3)**

LEAN MANUFACTURING SYSTEMS

Pre-Requisites: **None**

Course Outcomes:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

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

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

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

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

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

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

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

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

Learning Resources:

Text Books:

1. Design and Analysis of Lean Production Systems, Askin R G and Goldberg J B, John Wiley and Sons Inc., 2003.
2. Lean Tools: A Pocket Guide to Implementing Lean Practices, Micheal Wader, Productivity and Quality Publishing Pvt Ltd, 2002.

ME36030 3-0-0 (3)

DRONES AND AUTONOMOUS VEHICLES

Pre-Requisites: **Nil**

Course Outcomes:

CO1	Understand the basics of drones and autonomous vehicles
CO2	Knowledge of basic design requirements.
CO3	Knowledge about drone hardware and software
CO4	Knowledge about autonomous vehicles hardware and software

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Syllabus:

Introduction of different sensors used in drone like accelerometers, inertial measurement units, tilt and lidar sensor, gyro sensor. Principle of operation of various sensors used in drone; their roles and characteristics. Selection of appropriate sensor as per requirement. Calibration of sensors - compass sensor, Lidar Sensor, Gyro sensor. Concept of sensor calibration and using sensors in digital & analog mode

Introduction to different motors like DC, BLDC, servo motors, working, understanding its functioning. Studying BLDC motor using PWM techniques, speed torque characteristics, degree of freedom in drone.

Performing mathematical calculations like payload calculation, speed control techniques, thrust to weight ratio. Introduction of Inverted Pendulum and PID control. PWM Duty operation and Motor control by Encoder counter.

Introduction to Flight controller boards and its connectivity with different peripherals like sensors, ESC, GPS, RF module. Introduction Electronic Speed Controller and its connection with motor. ESC configurations using FCB to control speed and direction of motor. Introduction to flight control box and various commands used in it. Configuration techniques for FCB with various motors, GPS etc.

Fundamental applications of various types of drones. Implementation and handling of HD and thermal image camera for remote sensing and mapping. Introduction to photogrammetry. Image recognition with OpenCV using the drone camera. Fundamental techniques for stabilizing Gimbal.

Learning Resources:

Text Books:

1. Mastering Drone Design and Programming: A Comprehensive Guide to Learn Drone Design and Programming, Kris Hermans, Cybellium, 2023

Reference Books:

1. Drone Technology: Future Trends and Practical Applications, Sachi Nandan Mohanty, J. V. R. Ravindra, G. Surya Narayana, Chinmaya Ranjan Pattnaik, Y. Mohamed Sirajudeen, Wiley-Scrivener

ME36040 **3-0-0 (3)**

Industrial Safety and Risk management

Pre-Requisites: **None**

Course Outcomes:

CO1	Summarize safety regulations and standards for mechanical working industry
CO2	Formulate secure protocols for welding, gas cutting, and the storage and handling of gas cylinders.
CO3	Detail and recommend safety precautions for both cold forming and hot working of metals.
CO4	To grasp the basics of Quantitative Risk Analysis.
CO5	To gain understanding of controlling safety and relief systems, as well as the design activities associated with these systems.

Course Articulation Matrix:

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

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Safety in metal working machinery

General safety guidelines, principles, maintenance, and inspections for turning machines, boring machines, milling machines, planing machines, and grinding machines, as well as CNC machines. Safety principles, electrical guards, work area safety, material handling protocols, inspection procedures, and adherence to relevant standards and codes.

Safety in welding and gas cutting

Gas welding and oxygen cutting, resistance welding, arc welding and cutting, along with their typical hazards, required personal protective equipment, training requirements, safety measures for brazing, soldering, and metalizing, including explosive welding. Selection, care, and maintenance of associated equipment and instruments, safety protocols for the generation, distribution, and handling of industrial gases, including color coding, flashback arrestors, leak detection, pipeline safety, and the storage and handling of gas cylinders.

Safety in cold forming and hot working of metals

Safety considerations for cold working, power presses, feeding and cutting mechanisms, power press - electrical controls, setup, and die removal procedures, inspection, and maintenance of metal shears and press brakes. Hot working safety protocols - cover forging, hot rolling mill operations, safeguards within hot rolling mills, associated hazards, and control measures. Safety guidelines for gas furnace operations, cupolas, crucibles, ovens, foundry health hazards, proper material handling in foundries, cleaning and finishing within foundry processes

Quantitative risk analysis

Quantitative Risk Analysis –Component Techniques-System description-Hazard Identification-Incident enumeration-CPQRA Model construction – Consequence Estimation-Likelihood Estimation- Scope of CPQRA studies-Management of incident list-Applications of CPQRA-Limitations of CPQRA

Risk estimation

Risk measures, –Risk Indices-Individual and societal risk –Risk calculation for individual and societal risk – General approach and simplified approaches-other individual risk measures-Average rate of death-Equivalent social cost-Fatal accident rate-Individual hazard index-Mortality index and economic loss.

Risk management

Overall risk analysis – E and FI model– Methods for determining consequences effects: Effect of fire, Effect of explosion and toxic effect – Disaster management plan – Emergency planning – Onsite and offsite emergency planning – Risk management – First aids.

Learning Resources:

Text Books:

1. Philip Hagan “Accident Prevention Manual for Business and Industry”, N.S.C. Chicago, 13th edition, 2009.
2. “Health and Safety in Welding and Allied processes”, Welding Institute, UK, High Tech.
3. Publishing Ltd., London, 1989.
4. “Guidelines for Developing Quantitative Safety Risk Criteria” Centre for Chemical Process Safety CCPS American Institute of Chemical Engineers, Wiley, 2009. \\
5. Lees F.P., “Loss Prevention in Process Industries” Butterworth publications, London, 3rd edition, 2005.
6. Crowl D.A. and Louvar J.F., “Chemical Process Safety: Fundamentals with Applications”, 3rd Edition, Prentice Hall, 2011.

ME36042 2 - 0 - 2 (3)

Foundations of Lean Manufacturing

Pre-Requisites: None.
(Industry immersion Elective course for B.Tech, M.Tech & MBA)

Course Outcomes:

CO1	Translate qualitative observations into clear, structured, and objective reports suitable for decision-making.
CO2	Apply Lean manufacturing principles to address real-world challenges in production systems, including quality improvement and customization.
CO3	Use standard factory terminology and demonstrate effective teamwork, problem-solving, and brainstorming skills in a manufacturing context.
CO4	Analyze operational structures to identify inefficiencies caused by functional silos using Process Flow Diagrams and propose appropriate improvements
CO5	Evaluate material and information flow within a production system to identify waste and enhance process efficiency.
CO6	Apply Value Stream Mapping tools to visualize processes, identify bottlenecks, and recommend Lean improvements

Course Articulation Matrix:

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

Legend: 1 – Slightly; 2 – Moderately; 3 – Substantially

Detailed Syllabus

Lean Philosophy and Workplace Communication: Introduction to Lean Management philosophy and its counter-intuitive elements. Concepts of converting qualitative workspace observations into structured, objective statements suitable for formal reporting. Addressing contemporary challenges in mass manufacturing, including limited customization, operational flexibility, employee engagement, and craftsmanship-oriented approaches.

Factory Operations and Structural Inefficiencies: Introduction to common factory terminology across delivery, production, and procurement sectors. Understanding organizational operations, identifying functional silos, and addressing the distinct operational challenges they create within production systems. Application of Process Flow Diagrams to analyze structural inefficiencies and optimize layout configurations.

Workplace Dynamics and Collaborative Problem Solving: The role of teamwork and proactive engagement in a Lean manufacturing context. Methodologies for collaborative problem-solving, active group brainstorming, and individual task ownership. Management strategies and continuous development frameworks for sustaining an efficient, highly productive, and synchronized factory environment.

Material and Information Flow Analysis: Fundamental concepts of operational flow on the shop floor. Techniques for analyzing shop floor operations and identifying localized Lean wastes (Muda) during material movement. Examining the critical interface between information flow and material movement, and understanding how information triggers, regulates, and controls physical flow within a production line.

Value Stream Mapping and Process Optimization: Core introduction to the specialized family of Lean tools and their strategic applications across manufacturing organizations. Principles of Value Stream Mapping (VSM) to visualize end-to-end production processes. Developing a robust, problem-solving orientation toward identifying processing bottlenecks, mapping current-to-future states, and recommending value stream improvements.

Activities:

1. **SWAYAM Digital Self-Learning (provided by IIM Bangalore):** Watching curated video modules independently.
2. **Faculty Orientation**: Attending introductory, context-setting, and experience-sharing lectures.
3. **Guided Discussions:** Participating in sessions to reinforce core concepts and assign team tasks.
4. **Field Visits**: Conducting industry visits and direct on-site data collection.
5. **Team Problem-Solving**: Working in supervised group sessions to analyze factory operations.
6. **Project Report Drafting**: Collaboratively building and refining solutions for live factory issues.
7. **Progress Reviews**: Participating in mid-module faculty feedback and milestone check-ins.
8. **Student Presentations:** Delivering final team project presentations for evaluation.

Learning Resources:

Textbooks:

1. Shingo, Shigeo. A Study of the Toyota Production System: From an Industrial Engineering Viewpoint (Produce What Is Needed, When It's Needed), Productivity Press, 1989.
2. Womack, James P., Jones, Daniel T., and Roos, Daniel. The Machine That Changed the World: The Story of Lean Production-- Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World Industry, Simon & Schuster, 1990.
3. Liker, Jeffrey K. The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer, McGraw-Hill, 2004

Reference Books:

1. Ohno, Taiichi. Toyota Production System: Beyond Large-Scale Production, Productivity Press, 1988.
2. Monden, Yasuhiro. Toyota Production System: An Integrated Approach to Just-in-Time, 4th Edition, CRC Press, 2011.
3. Martin, Karen, and Osterling, Mike. Value Stream Mapping: How To Visualize Work and Align Leadership for Organizational Transformation, McGraw Hill Professional, 2013.
4. SWAYAM Digital Platform Curated Learning Material & Content Manuals (for practical industrial field assignment structures and video resources)

ME26046 **3-0-0 (3)**

Precision Motion Control in CNC Applications

Pre-Requisites: **NIL**

Course Outcomes (COs):

C01	Understand CNC machine tool architecture, drive systems, encoders, trajectory generatio controller interfacing for multi-axis motion control.
C02	Apply Laplace transforms and transfer functions to model system dynamics and analyze behav frequency domain analysis, including gain and phase margins.
C03	Analyze the stability of open- and closed-loop control systems using stability margins including Nyquist, Bode methods, and design basic controllers through pole-zero techniques.
C04	Evaluate control strategies including PID, advanced adaptive control, and sliding mode control for motion systems.
C05	Design and simulate trajectory generation algorithms and implement motion control for multi-axis machines, including real-time tuning and motion profile optimization

Course Articulation Matrix:

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

Legend: 1 – Slightly; 2 – Moderately; 3 – Substantially

Detailed Syllabus

CNC Machine Drive Systems and Axis Control: CNC machine tool architecture, drive systems, types of encoders and DAC/ADC devices: resolution and signal conditioning aspects. Motion control strategies: fundamentals of trajectory generation. Controller architecture design & interfacing for machine automation.

Laplace Transforms and System Modeling: Application of Laplace transforms for modeling and analysis of various physical systems. Transfer functions of drive systems of CNC machines, block diagram algebra and reduction. Analysis of open- and closed-loop configurations of CNC machines.

Frequency Domain Analysis: Frequency domain analysis using magnitude, phase, and delay; system behavior via Bode, Nyquist, and Polar plots; gain/phase margins, bandwidth, and resonance for stability; high-order system approximations for controller design

Control System Stability and Design: Stability of Open- and closed-loop control of CNC machines. Controller design using margins and phase and Nyquist criteria to assess stability. Design and tuning of P and PI controllers in practical systems. Application of pole-zero cancellation and pole-placement for system response shaping.

Advanced Controller Simulations: Design and tuning of PID controllers. Implementation of adaptive controllers: gain scheduling, Model Reference Adaptive Control (MRAC) and sliding mode control for uncertain systems. Feedforward compensation for enhanced robustness using MATLAB.

Axis and Motion Control: Control of single- and dual-axis systems with position and velocity control. Trajectory generation using linear, circular, trapezoidal, and S-curve profiles with acceleration and jerk limits. Development of programs of trajectory generation and its Real-time implementation and tuning of controller virtually using MATLAB.

Learning Resources:

Textbooks:

- Altintas, Yusuf. Manufacturing Automation: Metal Cutting Mechanics, Machine Tool Vibrations, and CNC Design, Cambridge University Press, 2012.
- Nise, Norman S. Control Systems Engineering, 7th Edition, Wiley, 2015.
- Suh, Suk-Hwan, et al. Theory and Design of CNC Systems, Springer Science & Business Media, 2008.
- Koren, Yoram. Computer Control of Manufacturing Systems, McGraw-Hill, 1983.
- Ogata, Katsuhiko. Modern Control Engineering, Prentice Hall, 5th Edition, 2010.
- Dorf, Richard C., and Bishop, Robert H. Modern Control Systems, Pearson, 12th Edition, 2010.
- Spong, M. W., Hutchinson, S., & Vidyasagar, M. Robot Modeling and Control, Wiley, 2006.

Reference Books:

- De Silva, Clarence W. Mechatronics: An Integrated Approach, CRC Press, 2005.
- Bolton, W. Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering, Pearson, 6th Edition.
- Siemens and Fanuc CNC Controller Manuals (for practical case studies and simulations)

ME46034 **2-0-2 (3)**

Design Thinking for Engineering Applications

Pre-Requisites: None — Basic engineering background is sufficient. ME 46033 is recommended but not mandatory.

Course Outcomes:

CO1	Understand the principles, mindsets, and methodology of Design Thinking and human-centred design in the context of engineering products, processes, and systems.
CO2	Apply user research methods — observation, contextual inquiry, and interviewing — to empathise with engineering stakeholders and synthesise insights into precise Point of View (POV) problem statements.
CO3	Generate and develop creative solution concepts for engineering design challenges using structured ideation methods, concept development tools, and cross-domain analogical thinking.
CO4	Construct low-fidelity prototypes and design structured tests to validate engineering design concepts, interpret user feedback, and make evidence-based iteration decisions.
CO5	Design a complete human-centred solution for a complex engineering problem by integrating Design Thinking methodology with awareness of system-level consequences and sustainability considerations.

CO-PO Correlation Matrix

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

Legend: 1 – Slightly; 2 – Moderately; 3 – Substantially

Detailed Syllabus

Foundations of Design Thinking: Introduction to DT — human-centred design; DT vs traditional engineering design process; Stanford d.school framework: Empathise, Define, Ideate, Prototype, Test — iterative cycle; Divergent and convergent thinking; the Double Diamond model; DT and Systems Thinking together; Case studies — Toyota Production System as DT; Tata Nano; vehicle instrument cluster reframing.

Empathise and Define: User research methods — observation, contextual inquiry, shadowing, semi-structured interviews; Synthesising research — affinity mapping, insight statements, moving from data to meaning; Point of View (POV) statement: [User] needs [need] because [insight]; How Might We (HMW) questions; problem framing and reframing; the Define stage as leverage point.

Ideate: Creative ideation principles — brainstorming, deferred judgement, psychological safety; Structured methods — brainwriting, SCAMPER, analogical thinking; TRIZ inventive principles; Concept development — morphological charts, concept sketching, concept combinations; Concept selection — Pugh matrix, weighted decision matrix; connecting ideation to ST leverage points.

Prototype and Test: Prototyping principles — fidelity spectrum; physical, process, and interface prototypes; Low-fidelity methods — paper prototyping, cardboard models, storyboards, process walk-throughs; Testing

protocols — test design, observation, capturing feedback; iteration and the pivot decision; Engineering prototyping in the DT process; failure as learning; documenting iteration rationale.

Design Thinking in Engineering Practice: DT in engineering product development — integrating DT into the V-model and stage-gate process; DT in process and system design — redesigning manufacturing processes and engineering interfaces; DT and sustainability — human-centred sustainability; rebound effect; circular economy design; Scaling design solutions — from prototype to pilot to implementation; capstone project reviews.

Experiential Practice and Capstone Project Work:

Student teams complete a full Design Thinking cycle on a real Mechanical Engineering problem: user research and empathy mapping, Point of View (POV) statement, How Might We (HMW) questions, structured ideation, low-fidelity prototype, user test, and iteration. Final deliverable: user research report, prototype documentation, test results, and a systems-aware intervention recommendation presented to the class in Week 14.

Learning Resources:

Text Books :

1. Nigel Cross, Engineering Design Methods: Strategies for Product Design, 5th Edition, John Wiley & Sons, 2021.

2. Tim Brown, Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation, HarperBusiness, 2009.

3. Nigel Cross, Design Thinking: Understanding How Designers Think and Work, Berg Publishers, 2011.

Reference Books:

1. Don Norman, The Design of Everyday Things, Revised and Expanded Edition, Basic Books, 2013.

2. IDEO.org, The Field Guide to Human-Centered Design, IDEO.org, 2015. (Free PDF at designkit.org)

3. Jeanne Liedtka & Tim Ogilvie, Designing for Growth: A Design Thinking Tool Kit, Columbia University Press, 2011.

4. Vijay Kumar, 101 Design Methods: A Structured Approach for Driving Innovation, John Wiley & Sons, 2013.

5. Darrell Mann, Hands-On Systematic Innovation, 2nd Edition, Creax Press, 2007.