CURRICULUM & SYLLABI

M.Tech. COMPUTER INTEGRATED MANUFACTURING

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 the 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. Computer Integrated Manufacturing

Program Educational Objectives

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

Program Articulation Matrix

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Program: M.Tech. Computer Integrated Manufacturing

Program Outcomes

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

CURRICULUM
M.Tech. Computer Integrated Manufacturing

1st Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME26001	Advanced Manufacturing Technology	3-0-0	3
2	ME36001	CNC Machines & Robotics	3-0-0	3
3	ME36003	Factory Physics	3-0-0	3
		Professional Elective – I	3-0-0	3
5		Professional Elective – II	3-0-0	3
6	ME36005	Advanced Design and Manufacturing Laboratory	0-1-2	2
7	ME36007	CNC and Robotics Laboratory	0-1-2	2
			Total Credits	**19**

2nd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME36002	Systems Approach to CIM	3-0-0	3
2	ME36004	Industry 4.0 and IIoT	3-0-0	3
3		Professional Elective – III	3-0-0	3
4		Professional Elective – IV	3-0-0	3
5		Professional Elective – V	3-0-0	3
6	ME36006	Manufacturing Simulation Laboratory	0-1-2	2
7	ME36008	Mechatronics and IIoT Laboratory	0-1-2	2
8	ME36096	Minor Project	0-0-0	2
			Total Credits	**21**

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME36089	Seminar and Technical Writing	0-0-0	2
2	ME36091	Summer Internship/Research Experience (SIRE)	0-0-0	2
3	ME36093	Comprehensive Viva-Voce	0-0-0	2
4	ME36097	Dissertation: Part-A	0-0-0	8
			Total Credits	**14**

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME36098	Dissertation: Part-B	0-0-0	12
			Total Credits	**12**

Professional Elective Courses:

Professional Electives – I & II		
S.No.	**Code**	**Course Title**
1	ME26023	Mechanical Behavior of Materials
2	ME26025	Micro and Nano Manufacturing Processing
3	ME26027	Mechanics of Metal Forming
4	ME26035	Finite Element Application in Materials Processing
5	ME36021	3D Printing Technologies
6	ME36023	Data Science in Manufacturing
7	ME36025	Augmented Reality and Virtual Reality
8	ME36027	Design for Manufacturability
9	ME26037	Computational Modeling of Materials
10	ME26043	Microwave Materials Processing: Principles and Applications
11	ME26045	Artificial Intelligence and Machine Learning in Materials Engineering
12	ME36029	Advanced CAD
13	ME36031	Materials, Energy Sources and Bonding Mechanisms
14	ME36033	Circular Economy
15	ME46027	Mathematical Methods in Engineering
16	ME46033	Systems Thinking for Engineering Applications

Professional Electives – III, IV & V		
S.No.	**Code**	**Course Title**
1	ME16024	Advanced Computational Fluid Dynamics
2	ME26026	Advanced Composite Materials and Processing
3	ME26028	Design and Analysis of Experiments
4	ME26042	Advanced Machining Processes
5	ME26044	Lasers in Manufacturing
6	ME36022	Supply Chain Management
7	ME36024	Modelling and Simulation of Manufacturing Systems
8	ME36026	Project Management
9	ME36028	Materials and Process Selection for Design
10	ME36030	Lean Manufacturing Systems
11	ME36032	Artificial Intelligence and Machine Learning for Mechanical Systems
12	ME36034	Product Lifecycle Management
13	ME26032	Rapid Tooling and Industrial Applications
14	ME36036	Soft Computing Techniques
15	ME36038	Drones and Autonomous Vehicles
16	ME36040	Industrial safety and Risk management
17	ME36042	Foundations of Lean Manufacturing
18	ME46024	Condition Monitoring and Fault Diagnostics
19	ME46028	Optimization Methods for Engineering Design
20	ME26046	Precision Motion Control in CNC Applications
21	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
Comprehensive Viva-Voce	2
Dissertation	20
Total Graded Credit Requirement	**66**

SYLLABI

M.Tech. Computer Integrated Manufacturing

1st Semester

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

Advanced Manufacturing Technology

Pre-Requisites: **None**

Course Outcomes:

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
CO5	Analyze the forming components using a high energy rate forming process

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

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

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.

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:

Text Books:

1. Mishra R. S., Friction Stir Welding and Processing, ASM International,2021.
2. Parmar R.S., Welding Processes and Technology, Khanna Publishers Year: 2019
3. J. Paulo Davim, Modern Machining Technology, A Practical Guide, Woodhead &Mechanical Engineering,2020.
4. Materials Characterization Author: ASM International Publication: ASM Handbook, Volume No. 10,2020.
5. ASM Handbook, ASM International, Volume No. 15,2021.
6. ASM Handbook, ASM International, volume No 14,1998.

ME36001 **3-0-0 (3)**

CNC Machines & Robotics

Pre-Requisites: **None**

Course Outcomes:

CO1	Classify and distinguish NC, CNC and DNC systems.
CO2	Develop manual and APT part programs for machining of complex parts.
CO3	Design structures for CNC machines.
CO4	Develop interpolation algorithms for control loops.
CO5	Classify and Design Application Specific end effectors for robots

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

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

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

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

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

Fundamental Concepts of Robotics: History, present status and future trends, robotics and automation, laws of robotics, robot definition, robotics systems and robot anatomy, specification of robots. Resolution, repeatability and accuracy of a manipulator.

Robot Drives: Power transmission systems and control robot drive mechanisms, mechanical transmission method, rotary-to-rotary motion conversion, rotary-to-linear motion conversion.

End Effectors and Sensors in Robotics: Types of End Effectors, Gripping Problems, Remote-Cantered Compliance Devices, Control of Actuators in Robotic Mechanisms, Types and Applications of Sensors in Robotics, Robot programming

Learning Resources:

Text Books:

1. Radhakrishnan.P, Computer Numerical Control (CNC) Machines, New Central Book Agency,2013.
2. Fu K S, Gonzalez R C, Lee C S, Control Sensing, Vision, Intelligence, McGraw Hill Book Co.,2021,2nd Edition"

Reference Books:

3. Mikell P Groover, Mitchell Weiss, Roger N Nagel, Nicholas G Odrey, Industrial Robotics - Technology, Programming and Applications (SIE), McGraw Hill Book Co., 2017.
4. Yoram Koren, "Computer Control of Manufacturing Systems", Tata McGraw Hill Book Co..2005.

ME36003 **3-0-0 (3)**

Factory Physics

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

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

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

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

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

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

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

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

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

Learning Resources

Text Books:

1. Krajewski U and Ritzman LP,Operations Management: Strategy and Analysis, Pearson Education Pvt. Ltd., Singapore, 2018.
2. Chase RB, Aquilano NJ and Jacobs RF,Operations Management for Competitive

Advantage, McGraw-Hill Book Company, NY, 2006.
3. Hopp WJ and Spearman ML,Foundations of Manufacturing Management, McGraw-Hill, NY, Third Edition, 2008.

Reference Books:

1. Sunil Chopra, Peter Meindl, and D.V. Kalra, Supply Chain Management, Pearson Education Pvt. Ltd., Singapore, 2016,6th Editon.
2. Eliyahu M Goldratt, A process of ongoing improvement,Gower Book, 2004,3rd Edition.
3. Eliyahu M Goldratt, Critical Chain, Gower Book, 1997.

Online Resources:

1. https://www.dbrmfg.co.nz

ME36005 **0-1-2 (2)**

Advanced Design and Manufacturing Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO1	Draw complex geometries of parts in sketch mode.
CO2	Create complex engineering assemblies using appropriate assembly constraints.
CO3	Practice on CAD data exchange formats used in design and analysis of Engineering components.
CO4	Analyse 2D/3D components using a FEA software.
CO5	Create models and analyze components manufactured through advanced manufacturing processes

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

LIST OF EXPERIMENTS

1. Introduction to Solid Modelling Packages
2. Working with sketch mode of Solid modelling Package
3. Working with creating features (Extrude & Revolve)
4. Working with various editing tools in Solid Modelling
5. Working with advanced modelling tools (Sweep, Blend & Swept Blend)
6. Assembly modelling using appropriate assembly constrains
7. Working with CAD Data Exchange formats: IGES, ACIS, DXF STL, AMF, STEP
8. Analysis of simple 2D/3D component using a FEA software
9. Fabrication of components using friction stir welding process
10. Fabrication of components using powder bed fusion process
11. Fabrication of components using stir casting and microwave casting
12. Demonstration of SEM and XRD Analysis

Learning Resources:

Text Books:

1. Steven Chapra, Applied Numerical Methods with MATLAB for Engineers & Scientists,McGraw-Hill in 2023,5th Edition.
2. Sham Tickoo, AutoCAD for Engineers & Designers" CADCIM Technologies,2023,26th Edition.
3. Verma G., Autodesk Fusion 360 Black Book, CAD CAM CAE Works, 2023, 7th Edition.

Reference Books:

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

Online Resources:

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

ME36007 **0-1-2 (2)**

CNC and Robotics Laboratory

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

LIST OF EXPERIMENTS

1. Simulation of turn components on CNC Simulator.
2. Turning of components on spinner.com lathe.
3. Turning of components on VDF lathe.
4. Milling simulation of 2D profiles on CNC Simulator.
5. Milling Simulation of Turbine blade on CNC Simulator.
6. Milling of 2D profiles on MaxMill CNC milling Machine.
7. Milling of 2D/ 3D profiles using Master Cam.
8. Milling of 2D/ 3D profiles using EdgeCam.
9. Generate and visualize CNC code using Virtual CNC Software. Design and fabrication of components using MOJO3D printer.
10. Welding using 6-axis articulated robot manipulator

Learning Resources:

Text Books:

1. NITWCNC Lab Manual,
2. John Stenerson, Kelly Curran, Operation and Programming, PHI, New Delhi, 2009.
3. TCC hang, RAWysk and HPWang, Computer Aided Manufacturing, PHI,New Delhi,2009.

Reference Books:

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

2nd Semester

ME36002 **3-0-0 (3)**

Systems Approach to CIM

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Manufacturing Automation: Automated Manufacturing Systems, Computerized Manufacturing Support Systems, Reasons and Strategies for Automation, Applications of Manufacturing Automation.

Automated Flow Lines: System Configurations, Work-part Transfer Mechanisms, Storage Buffers, Automated Flow Lines with and without Storage Buffers, Control and Analysis of Production Transfer Lines.

Manual and Automated Assembly Lines: Fundamentals of Manual Assembly Lines**,** Assembly Workstations and Work Transport Systems**,** Line Pacing and Coping with Product Variety**,** Analysis and Line Balancing of Single Model Assembly Lines**,** Design and Applications of Automated Assembly Systems**,** Parts Delivery Systems and Quantitative Analysis.

Advanced Material Handling and Storage Systems: Design Considerations in Material Handling**,** Automated Guided Vehicles (AGVs)**,** Automated Storage/Retrieval Systems (AS/RS)**,** Carousel Storage Systems and Engineering Analysis.

Automated Inspection Systems: Overview of Automated Identification Methods**,** Bar Code Technology and RFID**,** Other Automatic Identification and Data Capture (AIDC) Technologies.

Cellular and Flexible Manufacturing Systems: Part Families and Features Classification**,** Optiz of Parts Classification and Coding Systems**,** Production Flow Analysis and Composite Part Concept**,** Machine Cell Design and Applications of Group Technology**,** Quantitative Analysis and Grouping Techniques. Flexibility, Types Of FMS, FMS Components, Computer Control System, Human Recourses, FMS Applications and Benefits

Computer Aided Process Planning (CAPP), and Computer Integrated Manufacturing (CIM):

Retrieval and Generative CAPP Systems**,** Planning, Scheduling, and Analysis in CIM**,** Scope and Elements of CAD/CAM and CIM**,** Integration of Industry 4.0 and IoT Technologies in Manufacturing**,** Data Analytics.

Learning Resources:

Text Books:

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

Reference Books:

1. S. Kant Vajpayee, Principles of Computer Integrated Manufacturing, Prentice-Hall International, 1995.
2. Klaus Schwab, The Fourth Industrial Revolution, Crown Business, 2017.
3. Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things, Apress, 2016.

ME36004 **3-0-0 (3)**

Industry 4.0 and IIoT

Pre-Requisites: **None**

Course Outcomes:

CO1	Explore how Industry 4.0 transforms manufacturing through digitization of the value chain and digital twin technologies
CO2	Design, integrate, optimize mechatronic devices, and implement control systems for automation solutions
CO3	Select sensors/actuators, program, simulate, and innovate for addressing automation challenges effectively
CO4	Explore IIoT protocols, build simple IIoT systems with Arduino, ESP32, and Raspberry Pi for practical application

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

Syllabus:

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

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. Programmable Logic Controllers (PLCs): Architecture, Number Systems Basics of PLC Programming, Logic gates, Timers and Counters, Communication among HMI, PLC, SCADA, Fault diagnostics / troubleshooting. Application on real time industrial automation systems.

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.

Learning Resources:

Text Books:

1. Sudip Misra, Chandana Roy, Anandarup Mukherjee, Introduction to Industrial Internet of Things and Industry 4.0 CRC Press, 2020.
2. Gilchrist, Alasdair, Industry 4.0: The Industrial Internet of Things, United States: Apress, 2016.
3. Vijay Madisetti, Arshdeep Bahga, A Hands-on Approach", Internet of Things, University Press, 2020.
4. W. Bolton, Mechatronics, Electronic control systems in mechanical and electrical engineering, Pearson Education, 2023 7th Edition.
5. K P Ramachandran, GK Vijayaraghavan, M S Balasundaram, Mechatronics, Wiley, 2019 4th Edition.
6. Mechatronics Systems Design, Devadas Shetty, Cengage Learning, USA, 2021.

Reference Books:

1. Pethuru Raj,Anupama C. Raman, The Internet of Things: Enabling Technologies, Platforms, and Use Cases", CRC Press, 2012.
2. Adrian McEwen, Designing the Internet of Things, Wiley, 2015.
3. W. de Silva, Mechatronics: A foundation course, Clarence, CRC Press, 2010.
4. Robert H. Bishop. *The Mechatronics Handbook*, CRC Press, 2007,2nd Edition.
5. David G. Alcaiatore and Michel B. Histand, *Introduction to Mechatronics and Measuring Systems*, Mc.Graw Hill Int. Edition,2022,6th Edition.

Online Sources:

1. http://video_demos.colostate.edu/mechatronics
2. https://onlinecourses.nptel.ac.in/noc21_me129/preview

ME36006 **0-1-2 (2)**

Manufacturing Simulation Laboratory

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

List of Experiments:

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

Learning Resources:

Text Books:

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

References:

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

ME36008 **0-1-2 (2)**

Mechatronics and IIoT Laboratory

Pre-Requisites: **None**

Course Outcomes:

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, integrating SCADA, DCS, PLC, and HMI in manufacturing automation
CO3	Develop Arduino, ESP32 & Raspberry Pi microcontroller program using Thinker CAD & Python Programming.
CO4	Simulate and analyze PD, PI and PID controllers for a given physical system using MATLAB.
CO5	Design an IoT system with cloud infrastructure

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

Syllabus:

LIST OF EXPERIMENTS

1. Mobile Robot with P89V51RD2 microcontroller, Arduino, ESP 32 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
2. 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
3. SCADA, PLC & HMI – Programming, simulation and implementation using RSlogix, CODESYS, Rapid SCADA.
4. Control system simulation in MATLAB-Simulink and LabVIEW
5. Predictive Maintenance using Machine Learning: Use machine learning for predictive maintenance based on sensor data using MATLAB & Python Programming
6. Real-Time Data Monitoring: Monitor sensor data in real-time using cloud dashboards Using Python Programming

Learning Resources:

Text Books:

1. Mechatronics & IIoT Lab Manual
2. D. Boswarthick, O. Elloumi, and O. Hersent, M2M communications: A systems approach, Wiley, 2012, 1st Edition.
3. Bahga,V. Madisetti, Internet of Things, a hands-on approach, Create Space Independent Publishing Platform, 2014,1st Edition
4. Bahga,V. Madisetti, Cloud Computing, A hands-on approach, Create Space Independent Publishing Platform, 2013,1st Edition.
5. Jagadesesha T., T Gowda., Wiley Fluid Power, USA,2013

ME36096 **0-0-0 (2)**

Minor Project

Pre-Requisites: **None**

Course Outcomes:

CO1	Apply engineering principles to real-world projects
CO2	Plan and monitor project tasks individually or as a team
CO3	Demonstrate practical experience in project execution
CO4	Communicate project findings clearly through reports and presentations

Course Articulation Matrix:

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

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

ME36089 **0-0-0 (2)**

Seminar and Technical Writing

Pre-Requisites: **None**

Course Outcomes:

CO1	Consolidate ideas based on expert talks attended
CO2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO3	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	2	1	3
CO2	2	3	2	2	2	2
CO3	2	3	3	2	2	2

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

ME36091 **0-0-0 (2)**

Summer Internship/Research Experience (SIRE)

Pre-Requisites: **None**

Course Outcomes:

CO1	Apply engineering principles to real-world problems, gaining practical experience
CO2	Plan, manage and execute the work with ethical consideration
CO3	Review the social and environmental impact of the work
CO4	Communicate the learnings through report and presentation

Course Articulation Matrix:

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

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

ME36093 **0-0-0 (2)**

Comprehensive Viva-Voice

Pre-Requisites: **None**

Course Outcomes:

CO1	Comprehend the knowledge gained in the course work
CO2	Demonstrate the ability in problem solving
CO3	Communicate effectively using engineering terminology

Course Articulation Matrix:

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

ME36097 **0-0-0 (8)**

Dissertation Part-A

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

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

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

ME36098 **0-0-0 (12)**

Dissertation: Part-B

Pre-Requisites: **Dissertation: Part-A**

Course Outcomes:

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

Course Articulation Matrix:

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

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

Professional Electives

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

Mechanical Behavior of Materials

Pre-Requisites: **None**

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 ofmaterials
CO4	Select a characterization technique to evaluate the behaviour of materials

Course 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

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 behaviour, evaluation of strength and ductility parameters, Effect of strain rate and temperature on tensile behaviour, 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, Cyclicstress/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-plasticfracture mechanics, stress intensity parameter, J- integral and crack tip opening displacementas fracture criteria, standard procedures for experimental determination of these parameters.

Failure analysis: Analysing 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: Optical microscopy techniques, Quantitative metallography, Scanning electron microscopy: Image formation methods in SEM. Applications.

Learning Resources:

Text Books:

1. George E. Dieter, Mechanical Metallurgy, McGraw Hill, 2005,2nd Edition.
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. Richard W.Hertzberg, Richard P. Vinci, Jason L. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials,Wiley, 2012,5th Edition.

Reference Books:

1. M.F Ashbyand David R H Jones, Engineering Materials Introduction to Properties, Applications and Design,2010.
2. Marc Andre Meyers and Krishna Kumar Chawla,Mechanical behavior of Materials, 2009.

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

Micro and Nano Manufacturing Processes

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:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

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

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:

Text Books:

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

Reference Books:

1. Gabor L. Hornyak, H.F Tibbals, Joydeep Dutta & John J Moore, Introduction to Nanoscience and Nanotechnology, CRC Press, 2009.
2. Ray F. Egerton, Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, 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: **None**

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

COPO 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	

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:

Text Books:

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

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

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:

Text Books:

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

References Books:

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

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

Reference Books:

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

Syllabus:

I**ntroduction 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 Outco mes:

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

Syllabus:

Introduction to DFM
Overview of DFM and its importance, History and evolution of DFM**,** The relationship between design and 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 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 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:

Text Books:

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

Additional Resources:

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

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

Finite Element Application in Materials Processing

Pre-Requisites: **None**

Course Outco mes:

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

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 2D 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 super parametric 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:

Text Books:

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**

Computational Modeling of Materials

Pre-Requisites: None

Course Outcomes:

CO1	Select an appropriate method for simulation considering length and time scale
CO2	Develop a deep understanding of fundamental principles in materials modeling and simulation
CO3	Apply modeling and simulation techniques to solve real-world materials science problems
CO4	Make use of different scale modeling techniques to solve materials problem
CO5	Gain proficiency in computational techniques such as first-principles calculations, molecular dynamics, and Monte Carlo methods

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

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 nanocomposites

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/

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/

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

Advanced CAD

Pre-Requisites: **None**

Course Outco mes:

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		2	2	2	
CO3	3		3	3	2	
CO4	3		2	2	2	

1 - Slightly; 2 - Moderately; 3 - Substantially

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, Integration of CAD Tools with Industry 4.0 Technologies.

Learning Resources:

Text Books:

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

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

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 Mam ballykalathil 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

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/

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

Mathematical Methods in Engineering

Pre-Requisites: **None**

Course Outcomes:

CO1	Extend the methods of Applied Linear Algebra to engineering design problems
CO2	Solve problems involving Nonlinear Optimization in engineering
CO3	Simulate engineering systems using Numerical Methods.
CO4	Model physical systems using Differential Equations

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

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.

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.

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

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. Sunil Chopra and Peter Meindl, Supply Chain Management - Strategy, Planning and Operation, Pearson Education Asia, 2010, 4th Edition.
2. David Simchi-Levi, PhilpKamintry and Edith Simchy Levy,Designing and Managing the Supply Chain - Concepts Strategies and Case Studies, Tata-McGraw Hill, 2000, 2nd Edition.
3. John J Coyle, Managing Supply Chains A Logistics Approach', Cengage Learning, 2013, 9th Edition.
4. Jeremy F Shapiro, Modeling the Supply Chain', 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

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

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 Value Management, Project Risk Management.

Learning Resources:

Text Books:

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

Reference Books:

1. Eliyahu M Goldratt, The Critical Chain, Business novel, 1997
2. A guide to the Project Management Body of Knowledge, ProjectManagement Institute, 2008, 4th Edition.

Online Resources:

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

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

Design and Analysis of Experiments

Pre-Requisites: **None**

Course Outcomes:

CO1	Identify objectives and key factors in designing experiments.
CO2	Develop appropriate experimental design to conduct experiments.
CO3	Analyze 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	2	1	2	2		1
CO2	3		2	3		1
CO3	3	1	2	3		1
CO4	3		2	3		1
CO5	2		2	3		1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Fundamentals of Experimentation: Role of experimentation in rapid scientific progress, Historical perspective of experimental approaches, Steps in experimentation, Principles of experimentation.
Simple Comparative Experiments: Basic concepts of probability and statistics, Comparison of two means and two variances, Comparison of multiple (more than two) means & ANOVA.
Experimental Designs: Factorial designs, fractional factorial designs, orthogonal arrays, standard orthogonal arrays & interaction tables, modifying the orthogonal arrays, selection of suitable orthogonal array design, analysis of experimental data.
Response Surface Methodology: Concept, linear model, steepest ascent, second order model, regression.

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

Learning Resources:

Text Books:

1. Montgomery DC, Design and Analysis of Experiments, John Wiley & Sons, NY, 2019, 10th Edition.
2. Ross PJ, Taguchi Techniques for Quality Engineering, McGraw-Hill Book Company, NY, 2008.
3. Madhav S. Phadke, Quality Engineering using Robust Design, Prentice Hall, 1989.

Reference Books:

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

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

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

Advanced Composite Materials and Processing

Pre-Requisites: **None**

Course Outcomes:

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:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

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:

Text Books:

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”, Chapman and Hall, London, England,1994,1st Edition.
4. WD Callister, Jr., Adapted by R. Balasubramaniam, Materials Science and Engineering 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

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

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 andcomparing 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. M.F. Ashby, Engineering Materials, Elsevier, 2005, 4th Edition.
2. M.F. Ashby,Butterworth Heinemann, Materials Selection in Mechanical Design,2005.
3. Materials Selection and Design, ASM Publication, Vol.20: ASM, 1997.
4. Pat L.Mangonon,The Principles of Materials Selection and Design, Prentice Hall International, Inc.1999.

Reference Books:

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

ME36030 **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

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

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.

ME36034 **3-0-0 (3)**

Product Life Cycle Management

Pre-Requisites: **None**

Course Outco mes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

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

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

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

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

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

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

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

Learning Resources:

Text Books

1. John Stark, Product Lifecycle Management (Volume 1): 21st Century Paradigm for Product Realisation (Decision Engineering, Springer, 2020.
2. AnttiSaaksvuori, AnselmiImmonen, Product Lifecycle Management, Springer, 2008, 3rd Edition.
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, 5th Edition, Pearson, 2019.

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

Rapid Tooling and Industrial Applications

Pre-Requisites: **None**

Course Outcomes:

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	3	2	3

1 - Slightly; 2 - Moderately; 3 - Substantially

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:

Text Books:

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

Reference Books:

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

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

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

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

Advanced Machining Processes

Pre-Requisites: Machining Physics, Advanced Manufacturing Technologies

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

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:

1. El-Hofy, Hassan Abdel-Gawad, Advanced Machining Processes: Nontraditional and Hybrid Machining Processes, McGraw-Hill, 2005.
2. 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, TMH, 2010, 1st Edition.
2. S. Kalpakjain and S. R.Schmid, Manufacturing Engineering and Technology, Pearson, 2018, 7th Edition.
3. Amitabha Bhattacharyya, New technology, Institution of Engineers, 1973.

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

Drones and Autonomous Vehicles

Pre-Requisites: **None**

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

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

Reference Books:

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

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

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, 2009, 13th edition.
2. "Health and Safety in Welding and Allied processes", Welding Institute, UK, High Tech. Publishing Ltd., London, 1989.
3. "Guidelines for Developing Quantitative Safety Risk Criteria" Centre for Chemical Process Safety CCPS American Institute of Chemical Engineers, Wiley, 2009.
4. Lees F.P., "Loss Prevention in Process Industries" Butterworth publications, London, 2005, 3rd edition.
5. Crowl D.A. and Louvar J.F.,Chemical Process Safety: Fundamentals with Applications, Prentice Hall, 2011, 3rd Edition.

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)

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

Lasers in Manufacturing

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:

	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		
CO5	2	1		1		2

1 - Slightly; 2 - Moderately; 3 - Substantially

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

Laser care and safety

Learning Resources:

Text Books:

1. Thyagarajan K., Ajoy Ghatak, Lasers: Fundamentals and applications, Springer, 2010, 2nd Edition.
2. Ready J.F, Industrial applications of Lasers, Academic Press, 1997, 2nd Edition.
3. Willium T Selfvast,Laser Fundamentals, Cambridge Univ. Press, 2008.

Reference Books:

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

Online Resource:

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

ME46024 **3-0-0 (3)**

Condition Monitoring and Fault Diagnostics

Pre-Requisites: **None**

Course Outcomes:

CO1	Understand effective maintenance schemes in industries.
CO2	Apply vibration monitoring techniques for system diagnoses.
CO3	Apply oil analysis technique to diagnose the wear debris.
CO4	Identify nonconventional methods for machine diagnoses.
CO5	Develop modern technologies for effective plant maintenance.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Vibration based condition monitoring: Introduction, Type of failures, investigation and occurrences, Service failures, Principles of predictive maintenance, Predictive maintenance techniques, sensors for fault detection, Vibration transducers, Vibration basics, Spring-mass system: mass, stiffness, damping, System response, Nature of vibration, Harmonics, Limits and standards of vibration.

Data acquisition and analysis: Introduction, Vibration sensors, characteristics and mountings Collection of vibration signal, Vibration signature of active systems, Vibration monitoring equipment, Critical vibration levels, Conversion of vibrations to electrical signal, The fast Fourier transform (FFT) analysis, Frequency analysis techniques, Derived functions, Time waveform analysis, Phase signal analysis.

Machinery fault diagnosis and correcting faults: Introduction, Commonly witnessed machinery faults diagnosed, Simple vibration, Belt drives, Gear excitation, Rolling elements bearing, Balancing, Alignment, Resonance vibration control with dynamic absorbers.

Wear debris analysis: Introduction, Oil fundamentals, sampling methods, lubricant properties, Contaminants in used lubricating oils, Contaminants monitoring techniques, Spectrometric oil analysis, Magnetic chip detectors, Ferrograph particle precipitation, XRF, Temperature analysis.

Other predictive maintenance techniques: Performance trend monitoring, Performance monitoring systems, Introduction to non-destructive techniques, Ultrasound, Infrared thermography, Eddy current, Introduction to structural health monitoring

Learning Resources:

Text Books:

1. Rao J. S., Vibration Condition Monitoring, Narosa Publishing House, 2000, 2nd edition.
2. Isermann R., Fault Diagnosis Application, Springer-Verlag Berlin, 2011.

Reference Books:

1. Allan Davis, Hand book of Condition Monitoring, Chapman and Hall, 2000.

2. Choudary K K., Instrumentation, Measurement and Analysis, Tata McGraw Hill,2008.
3. Collacott, R. A., Mechanical Faults Diagnosis, Chapman and Hall, London, 1990
4. C Sujatha, Vibration and AcousticsTata McGraw Hill, 2017.

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

Optimization Methods for Engineering Design

Pre-Requisites: **None**

Course Outcomes:

CO1	Formulate a design task as an optimization problem.
CO2	Solve unconstrained optimization problems using corresponding methods.
CO3	Solve unconstrained optimization problems using corresponding methods.
CO4	Solve the nonlinear optimization problems with evolutionary methods

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

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

ME16024 **3-0-0 (3)**

Advanced Computational Fluid Dynamics

Prerequisites: NIL

Course Outcomes:

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

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

Course Articulation Matrix:

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

Syllabus:

Introduction: Revision of Fluid Mechanics and Heat transfer fundamentals.

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

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

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

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

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

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

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

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

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

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

Learning Resources:

Text Books:

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

Reference Books:

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

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 beha 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.