

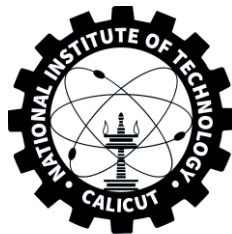
M.Tech.

IN

DIGITAL PRODUCT ENGINEERING AND MANUFACTURING

CURRICULUM AND SYLLABI

(Applicable from 2026 admission onwards)



तमसो मा ज्योतिर्गमय

Department of Mechanical Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode – 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of M.Tech. in Digital Product Engineering and Manufacturing

PEO1	Graduates apply their in-depth and advanced knowledge for fostering skills of analysing, formulating, defining and solving complex manufacturing challenges for productive and successful careers.
PEO2	Graduates demonstrate innovative and independent research work in academia/industry/R&D to enhance the knowledge base in digital product engineering and manufacturing and to disseminate the knowledge.
PEO3	Graduates exhibit a high level of professionalism, integrity, social responsibility and life-long independent learning ability.

Programme Outcomes (POs) of M.Tech. in Digital Product Engineering and Manufacturing

PO1	Independently carry out research/investigation and development work to solve practical problems
PO2	Write and present a substantial technical report/document
PO3	Demonstrate mastery in digital product engineering and manufacturing at a level higher than the requirements in the appropriate bachelor program.
PO4	Acquire and share in-depth knowledge in the area of digital product engineering and manufacturing
PO5	Analyse complex problems critically in the field of digital product engineering and manufacturing and arrive at optimal solutions.
PO6	Use modern computer/software tools to model and analyse problems related to digital product engineering and manufacturing.

CURRICULUM

Total credits for completing M.Tech. in Digital Product Engineering and Manufacturing is 75.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M.Tech. programme shall have the following Course Categories:

S No	Course Category	Minimum Credits
1.	Program Core (PC)	26
2.	Program Electives (PE)	12
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:

L: Lecture (One unit is of 50 minute duration)

T: Tutorial (One unit is of 50 minute duration)

P: Practical (One unit is of one hour duration)

O: Outside the class effort / self-study (One unit is of one hour duration)

PROGRAMME STRUCTURE

Semester I

S No	Course Code	Course Title	L	T	P	O	Credits	Category
1	ME6303E	Model Based Definition and Product Modelling	3	0	0	6	3	PC
2	ME6304E	Advanced Machining Technologies	3	0	0	6	3	PC
3	ME6305E	Geometrical Product Specification and Verification	3	0	0	6	3	PC
4		Elective 1	3	0	0	6	3	PE
5		Elective 2	3	0	0	6	3	PE
6		Institute elective course	2	0	0	4	2	IE
7	ME6307E	Industry Connect Seminar	1	0	0	2	1	PC
8	ME6394E	Advanced Manufacturing Technology Laboratory	0	0	3	3	2	PC
Total			18	0	3	39	20	—

Semester II

S No	Course Code	Course Title	L	T	P	O	Credits	Category
1	ME6315E	Additive Manufacturing Technologies	3	0	0	6	3	PC
2	ME6316E	AI and Smart Manufacturing	3	0	0	6	3	PC
3	ME6317E	Robotics and Automation	3	0	0	6	3	PC
4	ME6318E	Finite Element Methods in Manufacturing	3	0	0	6	3	PC
5		Elective 3	3	0	0	6	3	PE
6		Elective 4	3	0	0	6	3	PE
7	ME6393E	Project Phase I	0	0	0	6	2	PC
8	ME6395E	Digital Product Engineering Laboratory	0	0	3	3	2	PC
Total			18	0	3	45	22	—

Semester III

S No	Course Code	Course Title	L	T	P	O	Credits	Category
1	ME7394E	Project Phase II	0	0	0	9*	3	PC
2	ME7395E	Project Phase III	0	0	0	45	15	PC
Total			0	0	0	54	18	—

*To be completed during semester break. The number of hours is indicative only, and corresponds to a regular semester. Since the duration of the semester break is shorter, students are expected to devote more time per week. Furthermore, if Project Phase II is done as an internship, the working hours will be governed by the organization in which the internship is done.

Semester IV

S No	Course Code	Course Title	L	T	P	O	Credits	Category
1	ME7396E	Project Phase IV	0	0	0	45	15	PC
Total			0	0	0	45	15	—

List of Electives

S No	Course Code	Course Title	L	T	P	O	Credits
1	ME6311E	Modern Machining Processes	3	0	0	6	3
2	ME6321E	Design of Mechatronics Systems	3	0	0	6	3
3	ME6322E	Six Sigma with Design of Experiments	3	0	0	6	3
4	ME6324E	Industrial Machine Vision	3	0	0	6	3
5	ME6325E	Micro and Nano Manufacturing Processes	3	0	0	6	3
6	ME6327E	Quality Engineering and Management	3	0	0	6	3
7	ME6330E	Advanced Joining Technologies	3	0	0	6	3
8	ME6331E	Metal Additive Manufacturing: Technologies and Practice	3	0	0	6	3
9	ME6332E	Machining Dynamics	3	0	0	6	3
10	ME6333E	Laser Material Processing	3	0	0	6	3
11	ME6338E	Tolerance Engineering for Product Design and Manufacturing	3	0	0	6	3
12	ME6339E	Circular Production Systems and Green Manufacturing Technologies	3	0	0	6	3
13	ME6340E	Manufacturing Processes for Semiconductors and MEMS	3	0	0	6	3
14	ME6341E	Cyber Physical Machine Tools	3	0	0	6	3

List of Institute Electives

S No	Course Code	Course Title	L	T	P	O	Credits
1	IE6001E	Entrepreneurship Development	2	0	0	4	2
2	ZZ6002E	Research Methodology	2	0	0	4	2
3	MS6174E	Technical Communication and Writing	2	0	0	4	2

ME6303E MODEL BASED DEFINITION AND PRODUCT MODELLING

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the applications of computers in product development, product data management and product life-cycle management.

CO2: Create computer programs to implement various algorithms for generating geometric entities like line, circle and ellipse.

CO3: Create computer programs for performing 2D and 3D geometric transformations and projections of geometric entities.

CO4: Apply fundamental knowledge in mathematics to generate curves, surfaces and 3D objects.

CO5: Apply geometric reasoning principles to extract features from CAD data.

Computer applications in product development: Stages in Product development; Automation of functional activities, Product modelling; Geometric and Non-geometric data; Product Data Management (PDM); Product Life-cycle Management (PLM).

Model Based Definition: Product Manufacturing Information (PMI), 3D Functional Tolerancing and Annotations (FT&A), Common Information Model, Model Based Enterprise.

Overview of computer graphics: Mathematics for computer graphics; Graphics hardware and software; raster scan graphics; algorithms for generating line, circle and ellipse.

Transformations in computer graphics: 2D and 3D geometrical transformations: scaling; shearing; rotation; reflection; translation; Projections: parallel projections and perspective projections.

Modelling of curves and surfaces: Non-parametric and parametric curves: cubic spline; Bezier curves; B-spline curves; NURBS. Surface of revolution; sweep surface; linear Coons surface; Bezier surface; B-Spline surface.

Geometric modelling of 3D objects: Boundary Representation (B-Rep); Constructive Solid Geometry (CSG); Data structure for B-Rep and CSG models; Hybrid solid modellers; Feature based part modelling; Feature extraction from CAD models.

Product data exchange: Neutral file formats and exchange of product data; IGES and STEP

Feature extraction from CAD models: Geometrical, Topological and PMI data extraction from STEP files; Assembly modelling and extraction of data.

Hands on: Development of programs for transformations and modelling of curves and surfaces, use of commercial CAD packages for modelling and assembly of engineering components.

References:

1. Chang, K. H., *Product Design Modeling using CAD/CAE*, Academic Press, 2014
2. Rogers, D. F., and Adams, J. A., *Mathematical Elements of Computer Graphics*, McGraw Hill, 2017
3. Pande, S. S., *Computer Graphics and Product Modeling for CAD/CAM*, Narosa, 2012
4. Patel, C. D., Chen, C. H., *Digital Manufacturing*, Elsevier, 2022
5. Mortenson, M. E., *Geometric Modeling*, John Wiley & Sons, 1997
6. Ulrich, K. T., Eppinger, S. D., Yang, M. C. *Product Design and Development*, Mc Graw Hill, 2020
7. Eigner, M., *System Lifecycle Management - Engineering Digitalization*, Springer Vieweg, 2021
8. ASME Y14.41-2012, *Digital Product Definition Data Practices*, The American Society of Mechanical Engineers, New York, 2012
9. ISO 16792, *Technical Product Documentation–Digital Product Definition Data Practices*, International Organization for Standardization, Geneva, Switzerland, 2006

ME6304E ADVANCED MACHINING TECHNOLOGIES

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze the influence of tool angles, geometries of single and multipoint tools on cutting performance, define the various tool nomenclatures as per the industrial standards.

CO2: Analyze various cutting forces, cutting temperature, tool failures and recommend proper tool materials, tool geometry and cutting conditions for efficient machining.

CO3: Predict the cutting forces, power requirements in machining based on different analytical models, and based on mechanics of material removal.

CO4: Evaluate the surface characteristics of various machined surfaces and suggest ways to minimize various defects.

CO5: Explain latest technologies like hybrid additive manufacturing, ultra-precision machining, micro manufacturing, etc.

Mechanics of metal cutting; tool geometry-tool angle relationships in ASA, ORS, and NRS, effect of rake, lead and clearance angles; shear angle and its relevance, strain and strain rate in orthogonal cutting, oblique cutting, stress distribution along rake face, theories of Merchant, Lee and Shaffer, Oxley, etc. friction in metal cutting, Inserts-chip groove geometries; nomenclature, selection and applications in turning, milling, drilling, design concepts, new tool geometries, selection of operating conditions, carbide grade design, carbide coatings, ceramic, super hard grade design, effect of cutting variables on forces, tool failure analysis, theories of tool wear, measurement of tool wear, tool life and economics of machining.

Thermal aspects in machining; heat and temperature distribution, modeling of chip formation in metal cutting, modeling of machining characteristics in turning, milling, drilling, grinding, etc., measurement of cutting forces and cutting temperatures, abrasive machining processes, types and characteristics, surface analysis, methods of improving surface characteristics, surface integrity of machined parts, micro hardness and residual stresses.

Micro machining; tool-based micromachining methods, cutting edge radius effect, minimum uncut chip thickness, micro turning, micro milling, unconventional micromachining methods – micro EDM, micro WEDM. Ultra-precision machining; mechanism of material removal, methods and applications, mechanics, applications. nano surface generation, brittle versus ductile regime machining - ductile cutting of silicon wafers, nanometric cutting, chip formation, recent developments, focused ion beam and electron beam machining, hybrid additive manufacturing processes, materials and new developments.

References:

1. Knight, Winston A., and Boothroyd, G., 2005, *Fundamentals of Metal Machining & Machine Tools*, CRC Press, USA.
2. Bhattacharya, Amitabha, 2012, *Metal Cutting, Theory and Practice*, New Central Book Agency.
3. Chattopadhyay, A. B., 2017, *Machining and Machine Tools*, John Wiley & Sons, India.
4. Ghosh, A., and Mallik, A. K., 2014, *Manufacturing Science*, Affiliated East West Press Ltd.
5. Lal, G.K., 2007, *Introduction to Machining Science*, New age international publishers.
6. Shaw, M.C., 2012, *Metal cutting Principles*, Oxford Clarendon Press
7. Gibson I., Rosen.D., Stucker B., Khorsani M., 2021, *Additive Manufacturing Technologies*, Springer Nature, Switzerland.
8. Jain, V. K., 2012, *Micromanufacturing Processes*, CRC press, USA.
9. Dornfeld, D., and Lee, Dae-Eun, 2008, *Precision Manufacturing*, Springer, New York.
10. McGeough, J., 2002, *Micromachining of Engineering Materials*, Marcel Dekker, Inc., NY.
11. Taniguchi, N., 1996, *Nanotechnology: Integrated Processing Systems for Ultra-precision and Ultra-fine Products*, Oxford University Press Inc., NY.

ME6305E GEOMETRICAL PRODUCT SPECIFICATION AND VERIFICATION

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the basic concepts and symbols used in geometric product specifications including surface texture

CO2: Explain the basic terms in metrology as per the VIM

CO3: Calculate the uncertainty of a measurement according to International Standards.

CO4: Evaluate appropriate measurement systems for verification of dimensions, geometrical tolerances, surface texture, etc

Geometric Product Specifications: Geometric Dimensioning and Tolerancing: Necessity, Symbols, Calculation of straightness, roundness, Bonus Tolerances. Surface Texture Specification and Measurement: - Definitions, Stylus instruments, Filters and cut-off, computation of parameters like Ra, Rq, Rt, Rp, Rz, Rsm, etc., Bearing Area curve, autocorrelation function, Areal parameters

Geometric Product Verification Fundamentals: Introduction and review of vocabulary – Mass Production, Interchangeable manufacture, Errors, Accuracy, Calibration, etc. Measurement System Analysis (MSA). Selection of measuring instruments: Based on Maximum Permissible Error, MSA.

Measurement Uncertainty: Measurement Fundamentals - Measurement Uncertainty according to GUM, Type A Evaluation, Repeated measurements, Regression, Type B Evaluation, Calculation of combined standard uncertainty using Law of Propagation, Numerical Approach, Handling Correlated components, Expanded Uncertainty, Uncertainty and Resolution, Uncertainty and Conformity, Monte Carlo simulation.

Dimensional verification: Errors – Thermal, Geometric and Elastic deformation Coordinate Measuring Machines - Basics, Constructional features, Measurement process, Measurement strategy, Sampling strategy, Measurement Uncertainty Articulated Arm CMMs - Laser Trackers Machine Vision- Introduction, Image acquisition, File formats and compression, Imaging geometry, Pixel relationships, Preprocessing, Segmentation, Description, Recognition, Interpretation, Case studies.

References:

1. Kirkup, L. and Frenkel, R. B., 2006, *An Introduction to Uncertainty in Measurement Using the GUM*, Cambridge University Press, London.
2. Whitehouse, D., 2002, *Surfaces and Their Measurement*, Hermes Penton Science, London.
3. Hocken, J., ed., 2012, *Coordinate Measuring Machines and Systems*, 2nd ed., CRC Press, Boca Raton.
4. Demant, C., Streicher-Abel, B., and Garnica, C., 2013, *Industrial Image Processing*, 2nd ed., Springer-Heidelberg, New York.
5. Crowder, S., Delker, C., Forrest, E., & Martein, N., 2020, *Introduction to Statistics in Metrology*, Springer Nature, Switzerland.
6. Leach, R and Smith, S. T., 2018, *Basics of precision engineering*, Taylor and Francis, Boca Raton

ME6307E INDUSTRY CONNECT SEMINAR

Prerequisite: NIL

L	T	P	O	C
1	0	0	2	1

Total Lecture Sessions: 13

Course Outcomes:

CO1: Explain contemporary industrial practices, workflows, and standards in digital product engineering and manufacturing.

CO2: Identify emerging technologies, niche domains, and current challenges in digital product engineering and manufacturing from an industrial perspective.

CO3: Correlate theoretical knowledge and ongoing research with real-world industrial problems and solution strategies.

CO4: Demonstrate professional awareness and critical thinking by evaluating industry case studies, expert lectures, and interaction-based learning.

Industry experts will be invited to deliver lectures on niche domains and contemporary, industry-relevant topics in digital product engineering and manufacturing. These interactions will expose students to the current industrial practices, emerging technologies, real-world challenges, and application-driven perspectives, thereby strengthening the linkage between academic learning, research, and industrial requirements. Continuous assessment will be used for grade evaluation.

ME6394E ADVANCED MANUFACTURING TECHNOLOGY LABORATORY

Prerequisite: NIL

L	T	P	O	C
0	0	3	3	2

Total Practical Sessions: 39

Course Outcomes:

CO1: Grind and measure single point tool angles as per ASA.

CO2: Develop manual CNC programs using canned cycles and measure the dimensions.

CO3: Conduct tool life experiments, measure cutting forces and cutting temperature.

CO4: Conduct experiments on CNC EDM, WEDM, etc.

CO5: Familiarize with various advanced machines like Micromachining Centre, additive manufacturing machines, FSW machine, CMM, 3D Profilometer, Nanoindenter, SEM, AFM, XRD Machines, etc.

CO6: Conduct microstructure analysis, defect evaluation using NDT, etc.

Exercises on abrasive machining processes, measurements in universal measuring microscope, profile projector, metallographic studies using metallurgical microscope, measurement of tool angles and studies of tool wear in inserts using tool maker's microscope, experimental evaluation of cutting forces using dynamometers, studies and experiments on micromachining centre, programming and measurements with CNC coordinate measuring machine, surface texture analysis, experiments on non-destructive evaluation using ultrasonic testers, exercises on virtual instrumentation.

Exercises on CNC manual program and machine the component using CNC machining centre. Conduct studies on nanoindenter, SEM, AFM, 3D optical profiler, additive manufacturing machines, FSW machine, high speed camera and thermal imager. Studies and experiments on WEDM and EDM. Analysis of surface defects during machining.

List of Experiments:

1. Using suitable machine tool grind a single point cutting tool as per ASA, and measure the obtained tool angles.
2. Study the effect of process parameters on the surface roughness of mild steel specimen using CNC EDM & CNC WEDM
3. Write a CNC program (manual) using FANUC codes and machine the component, (production drawing of the part is given). Find out the required machines, cutting tools, cutting parameters and machine the component and measure the dimensions obtained and prepare the measurement chart. Comment on the obtained dimensional tolerances.
4. Measure the cutting forces during turning on lathe using strain gauge dynamometer, plot the tool life graph, and comment on the wear patterns observed on tool.
5. Conduct experiments to improve surface finish of cylindrical workpieces, using centreless grinding process. Comment on the selection of the grinding wheel, finish obtained, obtained geometrical accuracies.
6. Measure the specimen for defects given in the workpiece. Find out the measurements and defects using the following instruments; (a) Ultrasonic flaw detector, (b) Articulated arm CMM
7. Metallurgical evaluation of specimen using metallurgical microscope
8. Cutting force measurements using KISTLER dynamometer
9. Study and programming on CNC CMM
10. Study the optical 3D profilometer, high speed camera, thermal imager, nanoindenter
11. Use of SEM, AFM, XRD, FDM, FSW and other facilities

References:

1. Knight, Winston A., and Boothroyd, G., 2005, *Fundamentals of Metal Machining & Machine Tools*, CRC Press, USA.
2. Venkatesh, V. C., and Chandrasekaran, H., 1987, *Experimental Techniques in Metal Cutting*, Prentice-Hall of India.
3. Shaw, Milton C., 2004, *Metal Cutting Principles*, Oxford University Press., London.
4. Juneja, B. L., Sekhon, G. S., and Nitin Seth, 2003, *Fundamentals of Metal Cutting and Machine Tools*, New Age International, India.
5. Chattopadhyay, A. B., 2017, *Machining and Machine Tools*, Wiley, India.
6. Rao, P. N., 2010, *CAD/CAM: Principles and Applications*, Tata McGraw Hill, New Delhi.

ME6315E ADDITIVE MANUFACTURING TECHNOLOGIES

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Classify and explain different additive manufacturing systems and processes based on their capabilities and limitations for processing polymers, metals, ceramics, and other engineering materials

CO2: Apply strategies to improve the AM part quality by software modifications, utilizing 3-D file structures, and digital workflow of additive manufacturing

CO3: Derive analytical/mechanistic models related to various additive manufacturing phenomena and use them to predict required AM process responses.

CO4: Compare and contrast additive manufacturing processes with conventional manufacturing methods in terms of rate, quality, flexibility, part complexity, and cost

CO5: Critically evaluate the emerging applications of AM across major industries, including medical, dental, aerospace, vehicle structures, and consumer products, and gain hands-on experience in designing and fabricating AM parts.

Principles of Additive Manufacturing (AM): ISO/ASTM definition, generic AM process steps, characteristics of additive manufacturing AM and conventional manufacturing processes, hierarchical structure of AM technologies and product development, AM process classification methods- ISO/ASTM classification of AM processes and standard definitions, AM production economics.

3-D data files and digital work flow of AM: 3-D data digital forms and formats, generation of 3D data for AM using CAD and other routes, functions of AM software, digital work flow, tessellation and tessellation parameters, chordal error, stair step effects, adaptive slicing, STL formats and limitations, algorithms for error corrections, characteristics of various 3-D data file for AM, AMF and 3MF files, texture and color mapping, slicing algorithms, build file, layer data and machine data, process planning, part orientation and support generation.

Additive Manufacturing Processes: Material extrusion (MEX), solidification, bonding, process variation and materials, bio extrusion, direct ink writing, large area material extrusion

Powder bed fusion (PBF), process variants and commercial machines, materials and primary binding mechanisms, process parameters, applied energy correlations and scan strategies, process map, DSC curve for polymer laser sintering, metal PBF, analytical modelling, melt pool analyses, solidification behavior, residual stress, defects, microstructure and texture, mechanical properties, fatigue performance, post processing, laser and electron beam based PBF system

Directed energy deposition (DED), powder and wire feeding, energy source for DED processes, commercial DED machines and systems, materials and microstructure, melt pool characteristics, post-process for DED, capabilities and limitations, field-assisted AM.

Vat photo polymerization (VPP), process variation and materials, reaction mechanisms, photopolymerization process modeling, stereolithography apparatus (SLA), Digital light processing (DLP), Binder Jetting (BJ) process, printability of the fluids, print heads, and printing mechanism, commercial BJ systems, materials, multijet fusion, Material jetting, droplet formation, materials, and machine systems for MJ, Cold spray AM, Sheet lamination process, ultrasonic consolidation, microstructures and mechanical properties, hybrid additive manufacturing.

Design aspects and applications of AM: Design for additive manufacturing, ISO/ASTM design requirement and recommendations, topology optimization, generative design, emerging applications of AM in automotive, aerospace, energy, medical, construction, testing and certification of AM parts as per ASTM/ISO standards, evaluation and benchmarking, tolerance and finish of AM parts, guidelines for AM process selection, 4D printing, hands on experience in designing and fabricating AM parts.

References:

1. Gibson I., Rosen D., Stucker B., Khorasani M., 2021, *Additive Manufacturing Technologies*, Springer Nature, Switzerland
2. Tuhin M., Tarasankar D., 2023, *Theory and Practice of Additive Manufacturing*, John Wiley and Sons, USA
3. Kai Chua, C., Fai Leong K., 2019, *3D Printing and Additive Manufacturing: Principles and Applications*, World Scientific, Singapore
4. Ehsan T, Dyuti S., Obehi, O., Liravi I.F., Russo,P., Taherkhani, K, 2022, *Metal Additive Manufacturing*, 2022 John Wiley and Sons, USA
5. Patri. K. V., and W. Ma, 2004, *Rapid Prototyping: Laser-based and Other Technologies*, Springer, New York.
6. Kun Zhou, 2023, *Additive Manufacturing: Materials, Functionalities and Applications*, Springer Nature, Switzerland.
7. Chee K.C., Wong C., H., Yeong W.,2017, *Standards, Quality Control, and Measurement Sciences in 3D Printing and Additive Manufacturing*, Academic Press, USA
8. Martin Leary, 2020, *Design for Additive Manufacturing*, Elsevier, Netherlands.
9. Olaf D., Axel N, Damien M.,2019, *A Practical Guide to Design for Additive Manufacturing*, Springer Nature, Singapore.
10. Kun Zhou, 2023, *Additive Manufacturing Technology: Design, Optimization, and Modelling*, Wiley-VCH, Germany.

ME6316E AI AND SMART MANUFACTURING

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply Artificial Intelligence techniques for digital product engineering and manufacturing applications.

CO2: Explain the structure and use of STEP files for interoperability applications related to manufacturing system automation.

CO3: Develop digital models for manufacturing engineering system elements and propose a reference architecture for digital twin modelling.

CO4: Apply the concepts of digital thread and digital twin for automation of product/system development activities.

Introduction: Industry 4.0 and Industry 5.0, enabling technologies, business practices in the AI era, model-based enterprises, manufacturing system functions, Cyber Physical Production Systems, Human Machine Interaction for Smart Manufacturing, Industrial Foundation Models for intelligent manufacturing, Industrial Metaverse

AI Technologies in Manufacturing: Overview of AI technologies, Machine learning, Deep learning, Supervised and unsupervised learning algorithms, Feature engineering, Model selection, Data sources in manufacturing, sensors and actuators, Industrial IoT devices, communication protocols, techniques for data acquisition and real-time monitoring in industrial settings, Neural surrogates for materials simulations and use cases, Explainable AI (XAI), Agentic AI Orchestration, diffusion models of generative artificial intelligence in manufacturing, AI and Cobots, human-centric artificial intelligence for manufacturing, AI and extended reality, Case studies of AI applications for generative design, additive manufacturing, process planning, process optimisation, quality control, predictive analytics

Digital Thread and Smart Manufacturing: Digital product engineering practices, model-based system engineering, ISO 10303 standards for industrial automation systems and integration, information modelling and application protocols, model based design and 3D data files, digital thread, structure of STEP, QIF, semantics and ontology of STEP files, AP233-systems engineering, STEP files for multidisciplinary analysis and design, applications of STEP AP242 and STEP AP238, STEP AP 239 and Product life cycle supports

Digital Twin and Cyber Physical Production Systems: Smart factories, RAMI and other reference architecture, digital twin architecture, digital twin for systems, products and process,, modelling and simulation approaches, ISO 23247, digital representation of engineering system elements, universally unique identifier, OPC unified architecture, MT connect, digital twin for shop floors, interaction mechanism in digital twin systems, digital twins for prognostics and management of engineering systems, configuration of cyber physical production systems, case studies of digital twin implementation in manufacturing

References:

1. Soldatos, J., 2024, *Artificial Intelligence in Manufacturing*, Springer Nature, Switzerland.
2. Masoud S., Richard D B., 2024, *Artificial Intelligence in Manufacturing: Concepts and Methods*, Academic Press, USA.
3. Eigner, M., 2021, *System Lifecycle Management: Engineering Digitalization*, Springer Vieweg, Germany.
4. Prince, S. J. D., 2024, *Understanding Deep Learning*, MIT Press, USA
5. Wai Yie L., 2022, *Human Machine Collaboration and Interaction for Smart Manufacturing*, IET, UK.
6. Bi, Z. and Wang, X., 2020, *Computer Aided Design and Manufacturing*, Wiley-ASME Press, USA.
7. Sabina, J., Christian, B., Danda, B. R., Houbing, S., 2017, *Industrial Internet of Things: Cyber-manufacturing Systems*, Springer Nature, Switzerland.
8. Bi, Z., 2021, *Practical Guide to Digital Manufacturing*, Springer Nature, Switzerland.
9. Fischer, B. R., 2024, *Model-Based Enterprise: Achieving Lasting Value with MBD and MBE*, CRC Press, USA.
10. Tao, F., Zhang, M., and Nee, A. Y. C., 2019, *Digital Twin Driven Smart Manufacturing*, Academic Press, USA.

ME6317E ROBOTICS AND AUTOMATION

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Explain various concepts, strategies and functions of automation.
- CO2: Develop PLC programming for automated systems and analyze various continuous and discrete control systems.
- CO3: Identify sensors and actuators for industrial systems and control.
- CO4: Develop the kinematic and dynamic model of serial robotic manipulators.
- CO5: Design robot trajectories for industrial and service applications.

Introduction to automation: Mechanization and automation, definition, types of automation, merits and criticism, architecture of industrial automation systems, manufacturing plants and operations: automation strategies, basic elements of automated system, advanced automation functions, levels of automation.

Industrial control systems: Process and discrete manufacturing industries, continuous and discrete control systems: an overview of computer process control, fundamentals of automated assembly system, actuators and sensors: fluid power and electrical actuators, piezoelectric actuator; sensors for position, motion, force, strain and temperature.

Introduction to robotics: Robotics system, classification of robots, robot characteristics, kinematics for manipulator: frames and transformations, forward and inverse kinematics, DH representation, derivation of forward and inverse kinematic equations for various types of robots, applications of robots in manufacturing processes, autonomous mobile robots for digital factories.

Introduction to manipulator Jacobian: singularity, Jacobian in force domain, velocity propagation from link to link, static forces in manipulators, introduction to dynamic analysis: Lagrangian formulation, trajectory planning: joint space and cartesian space.

References:

1. Craig, John J., 2022, Introduction to Robotics: Mechanics and Control, Pearson Education, UK.
2. Saeed, B. Niku, 2019, Introduction to Robotics, Analysis, Systems and Applications, John Wiley & Sons, USA.
3. Spong, Mark W., and Vidyasagar, M., 2008, Robot Dynamics and Control, John Wiley & Sons, USA.
4. Paul, R.P., 1979, Robot Manipulators Mathematics Programming, Control, The Computer Control of Robotic Manipulators, The MIT Press, USA.
5. Schilling, Robert J., 1996, Fundamentals of Robotics, Analysis and Control, Prentice Hall of India.
6. Mittal, R.K., and Nagarath, I.J., 2003, *Robotics and Control*, Tata McGraw-Hill, New Delhi.
7. Groover, M., and Zimmers, E., 2014, *CAD/CAM-Computer Aided Design and Manufacturing*, PrenticeHall of India.
8. Shinskey, F.G., 1996, *Process Control Systems – Application, Design and Tuning*, McGraw-Hill, USA.
9. Groover, Mikell, 2016, *Automation, Production Systems, and Computer-Integrated Manufacturing*, Prentice Hall Press, India.

ME6318E FINITE ELEMENT METHODS IN MANUFACTURING

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply finite element methods for modelling and simulation of manufacturing processes.

CO2: Analyse the behaviour of various elements and solution schemes used in FEM for manufacturing.

CO3: Evaluate the results of numerical modelling and represent the solution data.

CO4: Analyse errors and their causes in modelling of manufacturing processes, and apply suitable rectification strategies.

Review of fundamentals of finite element method (FEM): Variational method, weighted residual method – element types: triangular and quadrilateral elements, axisymmetric, plate, shell and 3D elements – application of FEM software to model manufacturing processes – mesh generation and data visualisation.

Role of FEM in modelling and simulation of manufacturing processes: FE modelling of steady-state and transient problems – non-linear problems: material and geometric non-linearities – solutions using implicit and explicit methods – contact non-linearity: contact applications, contact kinematics, contact algorithms, issues in FE contact analysis and troubleshooting.

Modelling of manufacturing processes: Lagrangian and Eulerian formulations for modelling of machining and forming operations – Arbitrary Lagrangian-Eulerian (ALE) formulation – thermal modelling of manufacturing processes like arc welding, and casting – issues in non-linear FEA: solution methods and strategies, convergence and stop criteria, post-processing of results, troubleshooting.

References:

1. Reddy, J. N., 2019, *Introduction to the Finite Element Method*, McGraw Hill, India.
2. Reddy, J. N., 2021, *An Introduction to Nonlinear Finite Element Analysis*, Oxford University Press.
3. Cook, R.D., 2007. *Concepts and applications of finite element analysis*. John Wiley & Sons.
4. Dixit, P. M., Dixit, U. S., 2008, *Modeling of Metal Forming and Machining Processes*, Springer, UK.
5. Zienkiewicz, O. C., Taylor, R. L., Zhu, J. Z., 2013, *The Finite Element Method: Its Basis and Fundamentals*, Butterworth-Heinemann, UK.
6. Madier, D., 2020, *Practical Finite Element Analysis for Mechanical Engineers*. FEA Academy.
7. Gokhale, N. S., Deshpande, S. S., Bedekar, S. V., Thite, A. N., 2020, *Practical Finite Element Analysis*. Finite to Infinite, India.

ME6393E PROJECT PHASE I

Prerequisite: NIL

L	T	P	O	C
0	0	0	6	2

Course Outcomes:

CO1: Understand the process of reviewing and recording the literature

CO2: Understand the process of identification of the project problem

CO3: Apply the learning to define the problem and problem environment/boundary conditions

CO4: Develop a focused research learning, presentation and communication

Project Phase-1 is normally an initiation into the project.

Each student shall identify a topic of interest related to the core/elective courses undergone in the first semester of the M.Tech. programme. He/she shall get the topic approved by the project guide in the concerned area of specialization. The student is expected to conduct a literature survey and a systematic literature review using suitable frameworks like PICOT, SPICE, SPIDER, etc. A mid-semester evaluation shall be done by the guide. At the end of the semester, the student shall present the project problem and the related literature to the duly constituted evaluation committee. Grade will be awarded based on the student's work and presentation.

ME6395E DIGITAL PRODUCT ENGINEERING LABORATORY

Prerequisite: NIL

L	T	P	O	C
0	0	3	3	2

Total Practical Sessions: 39

Course Outcomes:

CO1: Attain expertise in 2D drafting, 3D modelling using various CAD software.

CO2: Ability to do modelling using various FEM software.

CO3: Acquire CNC programming capability to generate CNC codes using various CAM software.

CO4: Expertise in manufacture of components using CAM generated codes either through subtractive or additive manufacturing routes and measure the components utilizing advanced measuring equipment.

CO5: Gain proficiency in Robot programming.

CO6: Develop ladder logic diagrams for pneumatic and hydraulic circuits.

Model Based System Engineering: Product requirement analysis using SysML, demonstration of model based definition and engineering

Computer Aided Design: demonstration of part modeling, assembly and mechanism modeling

Finite Element Analysis: static structural analysis, coupled thermal stress analysis, exercise on geometry import and meshing, modal analysis, nonlinear analysis: geometric, material and boundary nonlinearities, transient structural analysis.

Computer Aided Manufacturing & Automation: Manual and CNC programming, generation of CNC codes from CAD geometries, introduction to robot accuracy and repeatability measurements, introduction to components and tools for automation.

List of Experiments:

1. Exercises on eliciting and analysis of product requirement using SysML
2. Exercises on part modelling (using different software)
3. Exercises on assembly modelling
4. Static structural analysis. (using different software)
5. Coupled thermal stress analysis.
6. Modal analysis to obtain natural frequencies.
7. Elasto-plastic analysis.
8. Transient structural analysis.
9. Generation of CNC codes from CAD models, including for sculptured surfaces – Implementation and measurements of fabricated components both subtractive and additive manufacturing routes
10. Design and testing of pneumatics/hydraulic-based automation circuits
11. Robot programming and repeatability & accuracy measurements

References:

1. Bi, Z. and Wang, X., 2020, *Computer Aided Design and Manufacturing*, Wiley-ASME Press, USA.
2. Zeid, I., 2009, *CAD/CAM: Theory and Practice*, Tata McGraw Hill, India.
3. Bhatt, N.D., and Panchal, V.M., 2014, *Machine Drawing*, Charotar Publishing House, India.
4. Popov, E.P., 2000, *Engineering Mechanics of Solids*, Prentice Hall of India.
5. Thompson, M.K., and Thompson, J.M., 2017, *ANSYS Mechanical APDL for Finite Element Analysis*, Butterworth-Heinemann, UK.
6. Zienkiewicz, O.C., Taylor, R.L., and Zhu, J.Z., 2013, *The Finite Element Method: Its Basis and Fundamentals*, Butterworth-Heinemann, UK.
7. ANSYS Mechanical APDL Documentation.
8. Groover, M.P., 2015, *Automation, Production Systems, and Computer Integrated Manufacturing*, Pearson Education, UK.
9. Craig, J.J., 1999, *Introduction to Robotics, Mechanics and Control*, Addison – Wesley, UK.
10. Esposito, A., 2003, *Fluid Power with Applications*, Pearson Education, UK.

ME7394E PROJECT PHASE II

Prerequisite: NIL

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: Develop a systematic procedure to solve the identified research/industrial problem

CO2: Analyze and Identify a suitable research methodology for solving the problem identified.

CO3: Apply the methods/tools learned to develop algorithms and solve the problem.

CO4: Analyze and interpret the results using tables and figures for visualization

CO5: Compile and construct a report by employing the techniques of academic writing critical analysis, and defend the thesis

CO6: Publish the findings in reputed journals, conferences or apply for patents

Project Phase II can be an extension of Phase I or internship outside during the summer semester break. Students shall continue to work on the problem identified in the project phase I or undergo internship outside. Students shall identify the methodology, apply for a preliminary work. The work should be suitable for communicating to a conference. The student shall submit a report. All the projects will be evaluated by a duly constituted committee.

ME7395E PROJECT PHASE III

Prerequisite: NIL

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Analyze and Identify a suitable research methodology for solving the problem identified.

CO2: Apply the methods/tools learned to develop algorithms and solve the problem.

CO3: Analyze and interpret the results using tables and figures for visualization

CO4: Compile and construct a report by employing the techniques of academic writing critical analysis, and defend the thesis

CO5: Publish the findings in reputed journals, conferences or apply for patents

The project work can be carried out at the institute or in an industry/research organization. Students desirous of carrying out project work in an industry or in other organizations have to fulfill the requirements as specified in the “Ordinances and Regulations for M. Tech.” The student is expected to complete the pilot study, redefine the project based on pilot study, decide on the appropriate research design, generate data/collect data, develop the algorithm and code, and obtain preliminary results in the third semester. There shall be evaluations of the project work during and at the end of the third semester by a committee constituted by the department.

ME7396E PROJECT PHASE IV

Prerequisite: NIL

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Analyze and Identify a suitable research methodology for solving the problem identified.

CO2: Apply the methods/tools learned to develop algorithms and solve the problem.

CO3: Analyze and interpret the results using tables and figures for visualization

CO4: Compile and construct a report by employing the techniques of academic writing critical analysis, and defend the thesis

CO5: Publish the findings in reputed journals, conferences or apply for patents

The project work will be extended to the end of the fourth semester. There shall be evaluations of the project work by a committee constituted by the department during the fourth semester. The student shall submit the thesis based on the recommendation of the departmental evaluation committee. There shall be viva-voce examination conducted by an evaluation committee with an external examiner.

“The project work/thesis will be considered for awarding Grade ‘S’ only if a paper, based on whether the project work is published/accepted for presentation at least in a Scopus indexed conference or a software copyright is granted. However, in exceptional cases, where the student and the guide want to submit a journal/conference publication at a later stage and if the student is able to submit the draft version of the journal/conference paper to the evaluation committee at the time of final presentation of the project work, the student may be considered for awarding ‘S’ grade if the committee finds the work to be excellent and guide ensures the submission of the work for journal/conference publication.”

Programme Specific Electives

ME6311E MODERN MACHINING PROCESSES

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze and model mechanics of USM, AJM

CO2: Model and develop electrical circuit for EDM and ECM.

CO3: Analyze and compare MRR, flow, heat transfer in beam processes.

CO4: Compare various modern machining processes and select best suitable process for a given application.

Introduction, classification. Mechanical processes: abrasive jet machining- mechanics of material removal. MRR model for brittle materials and ductile materials. Water jet machining- flow equations and MRR models. Abrasive water jet machining- mechanics of MRR, abrasive and water flow equations (2D). Economics of AWJM. Tribology of AJM. Ultrasonic machining-mechanics of metal cutting: grain throwing and hammering models. Vibration characteristics of prismatic bars and exponential horn. Differential equations for various transducer design. Design criteria, FEM modelling and design of USM systems. Economics of USM. Feed mechanism. Mechanical finishing processes: micro and nano finishing processes with smart fluids. Rotary ultrasonic machining.

Electro thermal processes: electro discharge machining, mechanics of material removal, MRR models. RC, RL, RCL – detailed circuit analysis and PWM and transistor-based power systems. Overdamped, critical damped, underdamped circuit in EDM. Surface roughness models. Servo systems in EDM and its selection. Dielectric systems- flow analysis. Heat transfer models in EDM and its effect on MRR and surface finish. Mathematical modelling and simulation. Wire EDM. Beam processes: laser, electron and ion beams, characteristics of beams and design of optical systems. Modelling of beam processes heat transfer models: gaussian, double, quadruple, egg shaped configuration heat source models. Modelling of beam processes and parametric study and flow modelling in fluid assisted beam processes.

Electro chemical and chemical processes: electrochemistry. Ion transfer kinetics- detailed analysis- Debye-Huckle-Onsager equations. Double layer. Kinematics and dynamics of ECM. MRR equations. Tool design and mathematical modelling. Tool design using FEM. Electrolyte flow analysis. Chemical machining, photo chemical processes. Electrochemical machining, modifications on basic ECM process: electro chemical grinding, electro chemical deburring, electro polishing, electro stream drilling, shaped tube electrolytic machining. Machine learning application in nontraditional machining processes, hybrid machining process.

References:

1. Anna, R., 2018, *Abrasive Technology*, Intech Open, UK.
2. Jagadish, and Gupta, K, 2020, *AWJM of Engineering Materials*, Springer, Switzerland.
3. Loan, D. M., 2004, *Tribology of AJM processes*, WA Publishers, USA.
4. Mattiat, O. E., 1971, *Ultrasonic Transducer materials*, Springer, New York.
5. Andreas, W. M., and Radovan K, 2012, *Principles of Abrasive Water Jet Machining*, Springer, Germany.
6. Kuila, S. K., 2012, *Parametric Analysis of Abrasive Water Jet Machining*, Lambert.
7. William R. T, 1989, *Ultrasonic Machining*, ASM International.
8. Marcel, K., 2021, *Rotary Ultrasonic Machining*, Springer, Germany.
9. Elman, C. J., 2001, *Electric discharge machining*, Society of Manufacturing Engineers.
10. Gary, F. B., 2017, *Nontraditional Manufacturing Processes*, Routledge.
11. John, I., 2005, *Laser Processing of Engineering Materials*, Butterworth-Heinemann.
12. Faust, C. L., 1971, *Fundamentals of Electrochemical Machining*, Electrochemical Society.
13. Jain, V. K., 2007, *Advanced Machining Process*, Allied Publishing Pvt. Ltd., India.
14. Bosez, G. K., 2021, *Machine Learning Applications in NC Machining Processes*, IGI Global.

ME6321E DESIGN OF MECHATRONICS SYSTEMS

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain various key elements or subsystems in mechatronics.

CO2: Develop PLC programming for automated systems and analyze control part.

CO3: Identify sensors, actuators and data acquisition systems for a given mechatronics system.

CO4: Analyze the requirements and advanced technologies of various subsystems in mechatronics system design through examples

Introduction to mechatronics: key elements in mechatronics, design process, types of design: traditional and mechatronics designs; advanced approaches in mechatronics; real time interfacing; elements of data acquisition system; case studies of mechatronics systems, identification of key elements of various mechatronics systems, examples.

Introduction to signals, system and controls; system representation, linearisation, time delays, measures of system performance; closed loop controller: PID controller, digital controllers, controller tuning, adaptive control; introduction to microprocessors, micro-controllers and programmable logic controllers components, PLC programming, examples.

Actuator and Sensors: fluid power and electrical actuators, piezoelectric actuator; sensors for position, motion, force and temperature, flow sensors-range sensors, ultrasonic sensors, fibre optic sensors, magnetostrictive transducer, selection of sensors; case studies on selection of actuators and sensors for mechatronics systems.

Advanced applications in mechatronics: sensors for condition monitoring, mechatronics control in automated manufacturing; artificial intelligence in mechatronics: fuzzy logic application in mechatronics, case studies and design of mechatronics systems.

References:

1. Shetty, D., Kolk, R A., 2015, *Mechatronics System Design*, Thomson Learning, USA.
2. Bolton, W, 2019, *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*, Pearson education Asia.
3. Neculescu, D, 2002, *Mechatronics*, Parson Education Asia.
4. Bishop, R H., 2005, *Mechatronics: An Introduction*, CRC Press, USA.
5. HMT Ltd, 2000, *Mechatronics*, Tata McGraw Hill, India.
6. Singh, B.P., 2004, *Microprocessors and Microcontrollers*, Galgotia Pub., India.
7. Petruzella, F D., 2010, *Programmable Logic Controllers*, Tata McGraw Hill, India.
8. Kant, K, 2010, *Computer Based Industrial Control*, PHI, India.
9. Merzouki, R., Samantaray, A.K., Pathak, P.M., Bouamama, B. Ould, 2013, *Intelligent Mechatronic Systems: Modeling, Control and Diagnosis*, Springer, London.

ME6322E SIX SIGMA WITH DESIGN OF EXPERIMENTS

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the basic concepts of the Six Sigma methodology and apply the simple QC tools.

CO2: Analyze data graphically and carry out hypothesis tests.

CO3: Plan and analyze factorial experiments

CO4: Use additional tools and software for analysis of experiments.

CO5: Compute the various metrics used in Six Sigma organizations.

Fundamentals: Introduction – origins, goal, DMAIC strategy, green and black belts – comparison with TQM, tools for six sigma – flowchart, checksheet, histogram, pareto analysis, cause and effect diagram, scatter diagram, control charts

Review of Statistics: Graphical tools: dot plot, box plot, histograms – normal distribution, central limit theorem, chi-square and F distribution, normal probability plotting - hypothesis testing: fundamentals, comparing sample with population, comparing two samples, paired tests, ANOVA.

Planning Experiments: Factorial experiments: terminology, effects and interactions, generating designs, Yates algorithm, testing significance of replicated factorials, developing models, residual analysis, number of replicates, judging significance in unreplicated factorials

Additional tools: testing for curvature, blocking, split plot experiments, response transformations, fractional factorial experiments, alias structure Planning and execution of a project: student to carry out and present results following DMAIC approach using DoE software

Other topics: Concept of control – funnel experiment and implications for management. Six sigma metrics : DPO, DPMO, defining opportunities, yield, throughput yield, normalized yield – process capability indices: Cp, Cpk, Cpm, Cpkm, confidence intervals, nonnormal variables– measurement system analysis. Design for six sigma – case-studies

References:

1. Breyfogle, F., 1999, *Implementing Six Sigma: Smarter Solutions Using Statistical Methods*, John Wiley & Sons, New York.
2. Harry, M., and Schroeder, R., 2000, *Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations*, Doubleday, New York.
3. Lawson, J. and Erjavec, J., 2000, *Modern Statistics for Engineering and Quality Improvement*, Thomson Duxbury, USA.
4. Montgomery, D. C., 2017, *Introduction to Statistical Quality Control*, John Wiley & Sons, Inc., New York.

ME6324E INDUSTRIAL MACHINE VISION

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Select suitable equipment for image acquisition, and illumination.
- CO2: Identify appropriate techniques for Preprocessing
- CO3: Use appropriate techniques for Segmentation.
- CO4: Apply algorithms for pattern classification.
- CO5: Implement image processing techniques for measurement and recognition.

Fundamentals: Introduction: types of inspection tasks, structure of image processing systems, examples. Image acquisition and illumination: solid state sensors, standard video cameras, other cameras, transmission to computer, optics, lighting. Image preprocessing: gray scale transformations, image arithmetic, linear filters, other filters. Positioning: positioning of individual object, orientation of individual object, robot positioning.

Segmentation and Identification: Segmentation: regions of interest, thresholding, contour tracing, edge based methods, template matching. Mark identification: bar code identification, character identification, identifying pin marked digits on metal, print quality inspection. Classification: as function approximation, instance-based classifiers, function based classifiers, neural network classifiers.

Recognition and Measurement: Presence verification: simple presence verification, simple gauging for assembly verification, presence verification using classifiers. Object features: basic features, shape descriptors, gray level features. Dimension checking: simple gauging, shape checking on punched parts, injection molded parts, high accuracy gauging of threads, calibration.

References:

1. Demant, C., Streicher-Abel, B., and Garnica, C., 2013, *Industrial Image Processing*, Springer-Heidelberg, New York.
2. Gonzalez, et al., 2017, *Digital Image Processing Using MATLAB*, McGraw Hill Education, USA.
3. Gonzalez & Woods, 2017, *Digital Image Processing*, Pearson, USA.
4. Davies, E. R., 2017, *Computer Vision: Principles, Algorithms, Applications*, Learning, Elsevier, Netherlands.

ME6325E MICRO AND NANO MANUFACTURING PROCESSES

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the principles of various micro and nano manufacturing processes.

CO2: Evaluate tools and methods used in micro and nano manufacturing.

CO3: Identify suitable manufacturing processes for fabrication of micro and nano features and devices.

CO4: Evaluate various metrology and characterization methods for micro and nano manufacturing processes.

Introduction to micro and nano manufacturing, applications – Scaling laws, types of scaling – Salient features of micro-machining and challenges in nano-, micro-, and meso- scale machining – Overview of micro-fabrication methods – chemical vapor deposition (CVD): basic principles of CVD, LPCVD, PECVD – physical vapor deposition (PVD): thermal evaporation and sputtering – lithography: optical and electron beam lithography – dry and wet etching.

Conventional micro-machining processes: micro turning, micro drilling, micro milling, micro grinding, diamond turn machining – Cutting force, surface roughness, chip formation, burr formation – Advanced micro-machining processes: micro electro-discharge machining: principle, system development, heat affected zone, applications – electro-chemical micro-machining: principle, types, applications – laser machining processes: types of lasers for micro-machining, laser micro-machining system – focused ion-beam micro-machining, ultrasonic micro-machining – Nano finishing: magnetorheological finishing, abrasive flow finishing, and allied finishing processes.

Inspection and metrology – various inspection and metrology based on optical, mechanical, charged beam and electrical – 3D optical profilometer, white light interferometry, focus variation methods – SEM – TEM – AFM – Force, vibration, and acoustic emission measurements.

References:

1. Jain, V. K., 2012, *Micromanufacturing Processes*, CRC press, USA.
2. Cheng, K., and Huo. D., 2013, *Micro-Cutting: Fundamentals and Applications*, John Wiley & Sons, Inc, USA.
3. Madou, M. J., 2002, *Fundamentals of Microfabrication*, 2nd ed., CRC Press, USA.
4. Cambell, S. A., 2001, *The Science and Engineering of Microelectronic Fabrication*, 2nd ed., Oxford University Press, UK.
5. Ohring, M., 2002, *Materials Science of Thin Films: Deposition and Structure*, 2nd ed., Academic Press, USA.
6. McGeough, J. A., 2001, *Micromachining of Engineering Materials*, CRC Press, USA.
7. Das, M., Jain, V. K., and Ghoshdastidar, P. S., 2012, *Nanofinishing Process using Magnetorheological Polishing Medium*, Lambert Academic Publishing, UK.
8. Leach, R., 2011, *Optical Measurement of Surface Topography*, Springer-Verlag Berlin Heidelberg.
9. Goodhew, P. J., Humphreys, J., and Beanland, R., 2000, *Electron Microscopy and Analysis*, 3rd ed., CRC Press, USA.

ME6327E QUALITY ENGINEERING AND MANAGEMENT

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Analyse the link between quality and cost and assess the impact of quality costs on an organization
CO2: Design and interpret control charts for variables and attributes for controlling and improving the quality of products, processes and services
CO3: Design different acceptance sampling plans and analyse the risks related to quality aspects while using them
CO4: Select and use the relevant quality and reliability tools for controlling and improving the dimensions of quality for products and services
CO5: Use software-based quality tools for the preparation of control charts, designing acceptance sampling plans and performing reliability test data analyses

Principles of Quality Management: Introduction, definitions of quality and related terms as per ASQ and ISO, dimensions of quality, tools for quality planning, quality control and quality assurance, quality costs and their categorifies, relationship between quality and quality costs, case studies of external failure costs, quality and engineering design process, quality function deployment (QFD), quality loss function, product control model and process control model for quality.

Process Control and Improvement: Process variation and sources, use of control charts, statistical basis of the control charts, derivation and choice of control limits, construction and interpretation of control charts for variables and attributes, rational sub groups, control chart sensitivity, OC curve, average run length, phase I and phase II control chart application, exponentially weighted moving average and the cumulative sum control charts.

Acceptance Sampling: The acceptance-sampling problem, lot formation and sampling, guidelines for using acceptance sampling, type a and type b oc curve, binomial nomograph, rectifying inspection, average outgoing Quality limit (AOQL), average total inspection, double, multiple, and sequential sampling, ASN curve, sampling systems, MIL STD 105E, switching rules, Dodge–Romig plans.

Industry Practices related to Quality: Quality standards, process capability analyses and matrices, six sigma approach, ISO/TS 16949 Automotive industry action group (AIAG) manuals, measurement system analyses, advanced product quality planning (APQP), production part approval process (PPAP), failure mode and effect analyses (FMEA), risk priority number.

Reliability Engineering: Introduction to reliability, reliability matrices, hazard rate function, system reliability, reliability testing, statistical distributions in reliability analysis, types of failure time, fitting models, warranty analyses

References:

1. Montgomery D.C., 2019, *Introduction to Statistical Quality Control*, John Wiley and Sons, USA
2. Mitra A., 2021, *Fundamentals of Quality Control and Improvement*, John Wiley and Sons, USA
3. Krishnamoorthi K., S., Pennathur, A, Krishnamoorthi. V., 2019, *A First Course in Quality Engineering*, CRC Press, Boca Raton.
4. Richard E. D., Sutherland J. W., Chang T., 2007, *Statistical Quality Design and Control: Contemporary Concepts and Methods*, Pearson, USA.
5. Edward G. S., Dean V. N., 2017, *Acceptance Sampling in Quality Control*, CRC Press, Boca Raton.
6. Automotive Industry Action Group (AIAG), 2010, *Measurement Systems Analysis Reference Manual*.
7. Elsayed E. A., 2020, *Reliability Engineering*, John Wiley and Sons, USA.
8. Pochampally, K. S., Gupta S. M., 2021, *Reliability Analysis with Minitab*, CRC Press, Boca Raton.

ME6330E ADVANCED JOINING TECHNOLOGIES

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the principles and process characteristics of various advanced joining processes.

CO2: Explain the dependence of process parameters and the evolution of material properties in joining

CO3: Optimize and design weld joint/equipment/tools/process parameters in welding

CO4: Describe the evolution of defects, its metallurgical aspects and inspection methods for the quality assurance in welding

Elements of weld setup, classification of welding processes, microstructural zones in welding, concept of continuity in welding, gas welding, arc welding; arc physics, concepts, processes and applications of manual metal arc welding, gas metal arc welding, gas tungsten arc welding, welding electrodes, power source characteristics, polarity, modes of metal transfer, CO₂ welding, submerged arc welding, electro slag and electro gas welding, plasma welding, resistance welding, underwater welding.

Friction welding: Concepts, types and applications; Friction stir welding: Metal flow phenomena, tools, process variables and application. Explosive, diffusion and ultrasonic welding: principles of operation, process characteristics and applications. EBW: concepts types and applications. LBW: physics of lasers, types of lasers, operation of laser welding setup, advantages and limitations, applications. Soldering: techniques of soldering, solders, phase diagram, composition, applications; brazing: wetting and spreading characteristics, surface tension and contact angle concepts, brazing fillers, role of flux and characteristics, atmospheres for brazing; adhesive bonding; cladding.

Heat flow, temperature distribution, cooling rates, influence of heat input; joint geometry, plate thickness, preheat, significance of thermal severity number. Epitaxial growth, weld metal solidification, columnar structures and growth morphology, effect of welding parameters; absorption of gases, gas/metal and slag/metal reactions. Phase transformations, weld CCT diagrams, carbon equivalent-preheating and post heating. Weldability of steels: low alloy steels, stainless steels use of Schaffler and DeLong diagrams; welding of cast irons. Welding of Cu, Al, Ti and Ni alloys: processes, difficulties, microstructures, defects and remedial measures. Process induced defects: significance, remedial measures, hot cracking, cold cracking, lamellar tearing, reheat cracking. Weldability tests, effect of metallurgical parameters. Weld testing and characterization, computational study through software packages.

References:

1. Parmer, R.S., 1997, *Welding Engineering and Technology*, Khanna Publishers, India.
2. Howard, B. Cary, 1998, *Modern Welding Technology*, Prentice Hall, USA.
3. Linnert, G.E., 1994, *Welding Metallurgy, Vol. I and II*, AWS, USA.
4. Granjon, H., 1994, *Fundamentals of Welding Metallurgy*, Jaico Publishing House, India.
5. Kenneth Easterling, 1992, *Introduction to Physical Metallurgy of Welding*, Butterworth Heinmann Ltd., UK.
6. Saferian, D., 1985, *The Metallurgy of Welding*, Chapman and Hall, UK.
7. Mishra, R.S., and Mahoney, M.W., 2007, *Friction Stir Welding and Processing*, ASM, USA.
8. Kou Sindo, 2002, *Welding Metallurgy*, Wiley, USA.
9. Nadkarni, S.V., 1996, *Modern Arc Welding Technology*, Oxford IBH Publishers, India.
10. Christopher Davis, 1994, *Laser Welding - A Practical Guide*, Jaico Publishing House, India.
11. Messler, Robert W., 2004, *Principles of Welding*, WILEY-VCH Verlag, Germany.
12. Lancaster, J.F., 1999, *Metallurgy of Welding*, Abington, Cambridge: Abington Pub., UK.
13. Little, A. Richard, 2017, *Welding and Welding Technology*, Tata McGraw Hill, India.

ME6331E METAL ADDITIVE MANUFACTURING: TECHNOLOGIES AND PRACTICE

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the fundamental principles and concepts of metal additive manufacturing (AM) technologies compared to traditional manufacturing methods.

CO2: Identify and evaluate the material and metallurgical aspects of different metal AM technologies for various critical and non-critical components

CO3: Apply modelling and simulation principles to metal AM to optimize the manufacturability and performance of metal parts.

CO4: Evaluate the process-structure-property relationship of metal AM parts using testing and characterization techniques.

CO5: Apply knowledge of safety protocols and ASTM/ISO standards in working with metal AM equipment and feed stock materials.

CO6: Analyse case studies and real-world applications of metal AM in industries such as aerospace, automotive, healthcare, and more.

Introduction to metal additive manufacturing (MAM): overview of metal additive manufacturing, brief history of metal additive manufacturing, advantages and limitations of metal additive manufacturing, comparison with traditional manufacturing methods, applications of MAM (medical, aerospace, automotive, moulds and tooling, remanufacture and repair, scanning and reverse engineering, engineered structures, functionally graded structures, etc., hybrid additive/subtractive systems, process steps.

Material aspects in MAM process: overview of metal powders; powder production: elemental and pre-alloyed metal powders, atomization process, reduction of compounds, electrolysis, additives; physical, chemical and microstructural characterization of powders; powder handling, storage, reuse and cleanliness. Physics of energy-material interaction: influence of lasers, electron beams and plasma arcs on microstructure and properties. Metallurgical aspects of MAM process: solidification, diffusion, phase transformation, surface energy, sintering, texture, non-equilibrium microstructure, residual stress; process-structure-property relationship, design of tailored structure for end application. Reuse of powder and their effects on properties and part performance.

MAM technologies: laser powder bed fusion, laser direct energy deposition, additive manufacturing with electron beams, metal printing with arc welding systems, binder jetting technology, solid state additive manufacturing technologies, ultrasonic consolidation, cold spray technology, nano and micro scale methods, other MAM technologies; mathematical models for additive manufacturing: transport phenomena models: temperature, fluid flow, and composition, buoyancy driven, tension driven free surface flow, case studies: numerical modelling of AM processes: powder bed fusion, droplet based, residual stress, optimal orientation, defects prediction, simulations for selection of parameters; post processing and inspection: support removal, defects and defect criticality, heat treatment, surface finishing, hot isostatic pressing, shot peening, influence of post processing on the mechanical properties of AM components, non-destructive testing, quality control techniques.

MAM standards and qualification: introduction to additive manufacturing standards, need for standards, standardization process. Fundamentals of qualification and certification - purpose, principles and applications, how AM qualification differs from conventional qualification process, quality management system for AM, creating a framework of metal AM qualification – material, machine, process, personnel, and part qualification, using standards to develop qualification framework, use cases with published AM international standards, future of AM qualification – model based rapid qualification; applications of MAM: aerospace and defense, medical and dental, automotive and transportation, jewelry and fashion, future trends and challenges.

References:

1. Gibson, I., Rosen, D., Stucker, B., and Khorasani, M., 2021, *Additive Manufacturing Technologies*, Springer, Switzerland.
2. Milewski, J. O., 2017, *Additive Manufacturing of Metals*, Springer, Switzerland.

3. Hosford, W. F., 2007, *Material Science: an intermediate text*, Cambridge, UK.
4. Bourell, D. L., Frazier, William, Kuhn Howard, and Seifi Mohsen, *ASM Handbook, Volume 24: Additive Manufacturing Processes*, USA.
5. German, R.M., 1994, *Powder Metallurgy Science, Metal Powder Industry*, USA.
6. ISO/ASTM 52904 *Additive manufacturing — Process characteristics and performance — Practice for metal powder bed fusion process to meet critical applications*.
7. ISO/ASTM 52930 *Additive manufacturing — Qualification principles — Installation, operation and performance (IQ/OQ/PQ) of PBF-LB equipment*.
8. ISO/ASTM 52902 *Additive manufacturing — Test artifacts — Geometric capability assessment of additive manufacturing systems*.
9. ISO/ASTM 52907 *Additive manufacturing — Feedstock materials — Methods to characterize metal powders*.

ME6332E MACHINING DYNAMICS

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Analyze and create dynamics model for turning, milling and grinding.
- CO2: Analyze energy equation and chatter in intermittent machining processes.
- CO3: Analyze controllability of dynamic strategies for machining.
- CO4: Explain and derive concepts behind chatter controllability.

Modelling of machining processes: Machining process modelling and analyses: Analysis of 2D and 3D machining processes. Static and dynamic loop stiffness, mechanistic modelling of 2D machining processes: processes, geometry, chip morphology, stress, strain, force modelling, 3D oblique cutting mechanics. Modelling of turning and milling processes: tool wear, tool life and cutting economics.

Vibration and modal analysis: Brief introduction of SDOF and MDOF systems, review of system matrix development. Introduction to modal analysis. Orthogonality properties and damped systems. Modal data acquisition: signal processing, transducer selection and design. Frequency response functions. Modal parameter extraction.

Machining dynamic analysis and chatter: Dynamic model for orthogonal cutting, machining instability and control. Machine tool dynamics. Dynamic cutting forces, stability analysis, single tooth, one-dimensional, linear time invariant models, feedback mechanisms and phase shifts, machining stability of turning. Stability solutions using traditional and frequency domain approaches. Stability of milling processes. High speed machining materials-induced vibration in single point diamond turning.

References:

1. Altintas, Y., 2012, *Manufacturing Automation*, Cambridge University, UK.
2. Jack H., 2021, *Integration and automation of manufacturing systems*.
3. Schmitz, T., and Smith, K., 2009, *Machining Dynamics*, Springer, New York.
4. Koenigsberger, F., and Tlustý, J., 1970, *Machine Tool Structures*, Elsevier, Netherlands.
5. Cheng, K., 2009, *Machining Dynamics*, Springer, United Kingdom.
6. Sweeney, G., 1971, *Vibration of machine tools*, The Machinery Publishing.
7. Weck, M., 1980, *Handbook of Machine Tools*, Volume 2 Wiley, London.
8. Rao, S. S., 2003, *Mechanical Vibrations*, Prentice Hall, New Jersey, USA.
9. Tobias, S.A., 1965, *Machine Tool Vibration*, Blackie and Son, London.
10. Armarego, E.J.A., and Brown, R.H., 1969, *The Machining of Metals*, Prentice-Hall, London.
11. Shaw, M. C., 1986, *Metal Cutting Principles*, Clarendon Press, Oxford, UK.
12. Stephenson, D. A., and Agapiou, J. S., 1997, *Metal Cutting Theory and Practice*. New York.
13. Youssef, H., and El-Hofy, H., 2020, *Traditional machining technology*, CRC Press, USA.

ME6333E LASER MATERIAL PROCESSING

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Analyze, model rate equations for industrial lasers.
- CO2: Derive heat transfer and flow models for beam process.
- CO3: Analyze various laser beam manufacturing processes.
- CO4: Derive and model laser beam machining for additive manufacturing.

Introduction to Lasers: basic principle of laser generation, stimulated emission; properties of laser beam, gain medium, optical resonator, pump source, laser beam delivery systems, introduction and basic fundamentals and characteristics of different industrial lasers: He-Ne, CO₂, Nd: YAG, excimer, fiber, diode and ultra-short pulse lasers, economics of laser application and safety issues.

Laser processing fundamentals: brief introduction to metal additive manufacturing. Laser beam interaction with metal and powder. Heat flow theory; energy balance during processing, heat flow, temperature distribution, detailed mathematical modelling of heat source models, Gaussian, uniform, circular, ellipsoidal, quadruple, double ellipsoid, egg configuration heat source models. Cooling rates, fluid flow in molten pool, free surface modelling, flow parameters modelling. Heat source modelling in COMSOL. Microstructure, zone of partial melting in additive manufacturing. Solidification with flow mushy fluid. Residual stresses and measurement in additive manufactured parts/laser processed parts. Modelling and simulations in laser material processing using commercially available software COMSOL and ANSYS.

Laser material processing applications; laser cutting and drilling, the challenges ahead for laser macro, micro and nano manufacturing, laser fusion cutting of difficult materials, laser dicing of silicon and electronics substrates, laser welding: laser microspot welding, laser hybrid welding, pulsed and continuous wave laser welding pulsed laser annealing technology, thick metallic coatings produced by coaxial and side laser cladding, laser micro/nano-fabrication techniques and their applications in electronics, laser-assisted additive fabrication of micro-sized coatings, lasers for additive manufacturing, multiphysics modelling of laser solid freeform fabrication techniques, laser shock peening; laser etching and paint stripping; LCVD and LPVD; laser hybrid machining; liquid assisted laser machining.

References:

1. Silfvast, W. T., 2004, *Laser Fundamentals*, Cambridge University Press, UK.
2. Orazio, S., 2010, *Principles of Lasers*, Springer, Switzerland.
3. Steen, W. M., and Mazumder, J., 2010, *Laser Material Processing*, Springer, Switzerland.
4. Kannatey-Asibu, E. Jr., 2009, *Laser Materials Processing*, Wiley, USA.
5. Dahotre, N. B., 2008, *Laser Fabrication and Machining of Materials*, Springer, Switzerland.
6. Lawrence, J., 2017, *Advances in Laser Materials Processing*, Woodhead Publishing, USA.
7. Grigoriev, S. N., *Advances in Laser Materials Processing*, MDPI Books, Switzerland.

ME6338E TOLERANCE ENGINEERING FOR PRODUCT DESIGN AND MANUFACTURING

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze the impact of product drawing specifications and interpretation on inspection and quality assurance in product manufacturing.

CO2: Design tolerances for unconstrained, orientation-constrained, and location-constrained fits between parts, including threaded fastener assemblies.

CO3: Perform tolerance stack-up analysis for multi-part assemblies using analytical, graphical, and vector-based methods.

CO4: Utilize STEP AP 242 and QIF standards for automated tolerance evaluation.

Product Development: Product development process and organizations, product specifications, product architecture, model-based approach to product development, digital thread and integrated product development, Digital Product Specifications product lifecycle, design-manufacturing integration, Design intent, Materials selection and manufacturability considerations, tolerancing for design and manufacture, tolerance stack up in manufacturing, ISO 17450: impact of the drawing specifications on inspection

Basics of Tolerances: Dimensions and Tolerances overview, Symbols of the ISO 1101 and ISO 5458, The feature of size concept, Basic Rules of ISO 22081, ISO and ASME standards for tolerancing, tolerancing schemes, parametric, geometric, and operational tolerances

Tolerance Engineering: Tolerance Design for Unconstrained Fits Between Two Parts, Default Form Control Implied by Limits of Size, Fit and Play Formulas, Precision fits, International Tolerance Grades, Preferred Fits, Tolerance Design for Orientation-Constrained Fits Between Two Parts, The Fit Boundary and the Theoretical Gage, Tolerance Design for Location-Constrained Fits Between Two Parts, Assemblies with Threaded Fasteners, Tolerance of Profile, Default Tolerancing Methods, Orienting or Locating with Respect to an Axis or Center Plane

Tolerance Design and Analysis of Multi-Part Assembly: Tolerance stack-up analysis in assemblies, Two-Part Fit, four-part fit, Vector-Based Analysis Procedure, Analytical Method, and Graphical method, variational geometric theory for tolerance synthesis and analyses, sources of variation in assembly, tolerances of form and assembly, tolerance evaluation methods, computer-aided tolerance analyses, Quality Information Framework (QIF) and STEP AP 242, STEP-based automatic tolerance analyses

References:

1. Ulrich, K. T., Steven D. E., Maria C. Y., 2020, *Product Design and Development*, McGraw-Hill Education, USA.
2. Zhang, H-C., 1997, *Advanced Tolerancing Techniques*, Springer Nature, Switzerland.
3. Tornincasa, S., 2024, *Technical Drawing for Product Design*, Springer Nature, Switzerland.
4. Etesami, F., 2024, *Geometric Tolerancing Applications to Machine Design*, Springer Nature, Switzerland.
5. Creveling, C. M., 1996, *Tolerance Design: A Handbook for Developing Optimal Specifications*, Prentice Hall, India.
6. Fischer, B. R., 2018, *Mechanical Tolerance Stackup and Analysis*, CRC Press, USA.
7. Madsen, D. A., and Madsen, D. P., 2017, *Engineering Drawing and Design*, Cengage, USA.
8. Pfeifer, T., 2002, *Production Metrology*, Oldenbourg Verlag, Germany.
9. Yang, Y. S., Gadomski, A. M., and Mitchell, J. A., 2014, *Information Modelling for Interoperable Dimensional Metrology*, Springer Nature, Switzerland.

ME6339E CIRCULAR PRODUCTION SYSTEMS AND GREEN MANUFACTURING TECHNOLOGIES

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply circular economy principles and the 9R framework to analyse circularity performance of production systems.
CO2: Perform a simplified Life Cycle Assessment (LCA) for manufactured products as per standards
CO3: Analyse different footprints for industrial sustainability assessment
CO4: Apply green manufacturing techniques and energy efficiency strategies to reduce processing energy in manufacturing operations.

Introduction: Introduction to Circular Economy, ISO 59004 standard-Vocabulary, principles and guidance for implementation, Measuring and assessing circularity performance, climate change policy and adaptations, Extended Producer Responsibility, linear and circular models, applying the 9R framework to production scenarios. Circular Production Systems and Industry 5.0, Industrial Symbiosis: a detailed analysis of the Kalundborg case study.

Circular Design and Life Cycle Assessment: Design for Circularity (DfC): Design for Disassembly (DfD), Eco-design and labels, Product Service Systems, Material Selection: Criteria for renewable, and recyclable materials, Sustainability and traceability of the recovery of secondary materials, Life Cycle Assessment (LCA): Methodology for assessing environmental impact from cradle to grave, ISO 14044-the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA), LCA of vehicles, Vehicle weight minimization, and lean and green manufacturing for automotive and aerospace industries.

Cleaner Production: Sustainable Products and Services, Sustainability Indicators, Environmental and Social aspects of ESG in product development, Global reporting initiative (GRI), Cleaner Production Practices, Assessment of Carbon Footprint, Water Footprint, and Embodied Energy of Production, Material Flow Analyses, Energy Efficiency in Factory Utilities, Overview of ISO 14001 (Environmental Management) and ISO 50001 (Energy Management Systems), Environmental Sustainability Assessment.

Green Manufacturing: Principles of Green Manufacturing, Processing Energy in Unit Manufacturing Process, Sustainability and Energy Efficiency of Manufacturing Processes, Analyses of Energy Reduction in Manufacturing and Assembly Operations, Remanufacturing Operations, the technical process of acquisition, disassembly, cleaning, inspection, and reassembly, Green Materials, and Processing methods, Synergy between design and sustainability in additive manufacturing, Sustainable Machining Strategies, Green Manufacturing through Clean Energy Supply.

References:

1. Francisco J, Gomes da Silva, Ronny M G, 2020, *Cleaner Production*, Springer Nature, Switzerland.
2. José Augusto O, Diogo A. L. S, Fabio N. P. Yovana M. B. S., 2020, *Life Cycle Engineering and Management of Products*, Springer Nature, Switzerland.
3. Braden R. A., Allenby. B. R., 2009, *Industrial Ecology and Sustainable Engineering*, Pearson, USA.
4. John W. S, David A. D., and Barbara S. L., 2018, *Energy Efficient Manufacturing*, John Wiley & Sons, USA.
5. Nand K. J., 2016, *Green Design and Manufacturing for Sustainability*, CRC Press, USA.
6. Jiri Klemes, Ferenc F, Igor B, and Petar V., 2011, *Sustainability in the Process Industry*. McGraw-Hill, USA.
7. David A. Dornfeld, 2014, *Green Manufacturing: Fundamentals and Applications*, Springer Nature, Switzerland.

ME6340E MANUFACTURING PROCESSES FOR SEMICONDUCTORS AND MEMS

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Explain the basic principles and working concepts of Micro-Electro-Mechanical Systems (MEMS).
- CO2: Assess the commonly used micro-fabrication processes involved in MEMS device development.
- CO3: Interpret the mechanical and electrical behaviour of MEMS devices under different operating conditions.
- CO4: Analyse the sensing and actuation mechanisms used in MEMS-based systems.
- CO5: Identify and explain real-world applications of MEMS across engineering and technological domains.

MEMS Introduction – evolution of micro and nano scale engineering systems – emerging trends in microsystems – fundamentals of microtechnology: definitions, terminology, and scaling effects – intrinsic characteristics of MEMS: miniaturization, multifunctionality, system integration – materials used in MEMS fabrication: silicon, polymers, metals, ceramics, and composite materials – silicon as a MEMS material: crystal structure and anisotropy – properties of silicon: mechanical, electrical, thermal, and piezoresistive properties – emerging materials for MEMS: piezoelectric materials, shape memory alloys, and polymer-based MEMS.

Fabrication technologies: thin film deposition – photolithography, ion implantation, diffusion, oxidation, chemical vapour deposition, physical vapour deposition – etching: dry etching, plasma etching, wet etching – bulk and surface micro machining – LIGA process: principle, process steps, and applications – wafer bonding techniques – high-aspect-ratio microfabrication methods – additive and hybrid manufacturing approaches for MEMS – bulk micromachining techniques and applications – fabrication of micro-needles, micro-nozzles, and cavities – surface micromachining concepts – sacrificial layer processes – fabrication of cantilevers, membranes, and micro-motors – comparison of bulk and surface micromachining approaches.

Sensing and actuation techniques – electrostatic actuators – thermal sensing and actuation; piezoresistive sensors: piezoresistive sensor materials, stress analysis of mechanical elements, applications of piezoresistive sensors – piezoelectric sensing and actuation – magnetic actuation – applications of micro- and nano- electro-mechanical systems in sensors, actuators, biomedical devices, RF systems, automotive systems, and consumer electronics – future trends and challenges in MEMS manufacturing.

References:

1. Madou M. J., 2021, *Fundamentals of Microfabrication*, CRC Press, USA.
2. Ghodssi R., Pinyen, 2011, *MEMS Materials and Processes Handbook*, Springer Science Business Media, New York.
3. Hsu T.-R., 2020, *MEMS and Micro systems: Design, Manufacture and Nanoscale Engineering*, Wiley, USA.
4. Hsu T.-R., 2023, *MEMS & Micro systems Design and Manufacture*, TMH, India.
5. Campbell S. A., 2008, *Fabrication Engineering at the Micro and Nanoscale*, Oxford University Press, USA.

ME6341E CYBER PHYSICAL MACHINE TOOLS

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Identify and explain the system components for the development of Cyber Physical Machine Tools
- CO2: Develop system-level architecture for the design and development of Cyber Physical Machine Tools
- CO3: Create and execute CNC part programs for drilling, turning, and milling operations
- CO4: Apply knowledge of machine tools and processes to develop Machine Tool Digital Twins

Industry 4.0, future of machine tool design and control. Machine-to-Machine (M2M) communication and Internet of Things (IoT) – fundamentals and architecture, Smart manufacturing.

Cyber-physical machine tools (CPMT): Generic system architecture of CPMT, components and functions, Physical machine tool and processes, Machine Tool Digital Twin (MTDT), Cloud-based services, Smart Human-Machine Interfaces (HMIs); Real-time manufacturing data acquisition, Communication protocols and communication architecture; Information Models in CPMT – MTConnect and OPC UA based information models.

CNC machine tools: Types of CNC machine tools; Design considerations and constructional features of CNC machine tools; Mechatronic elements – Sensors, actuators and servo drives; Power drives: Mechanical drives - ball screws, spindles and guide ways; hydraulic drives and electric drives; design of machine tool structures

Machine control unit (MCU), interpreter, interpolator, acceleration/deceleration control, control loops, control strategies, PID controllers

CNC programming – manual part programming, computer-aided part programming. Generation of CNC programming using CAM modules, hands-on training in CNC machining simulators.

STEP-NC System: STEP (ISO 10303) and STEP-NC (ISO 14649), STEP-NC Data model, STEP-NC Part programming, STEP-compliant CNC

Case studies in the development of CPMTs

References:

1. Mehta, N. K., 2020, *Machine Tool Design and Numerical Control*, 3rd ed., Tata McGraw-Hill, India.
2. Suh, S-H., Kang, S. K., Chung, D-H., Stroud, I., 2008, *Theory and Design of CNC Systems*, Springer, London
3. Boothroyd, G., and Knight, W. A., 2005, *Fundamentals of Metal Machining and Machine Tools*, 3rd ed., McGraw Hill, USA.
4. Joshi, P. H., 2007, *Machine Tools Handbook – Design and Operation*, Tata McGraw Hill, India.
5. Xu, X., and Nee, A. Y. C., 2009, *Advanced Design and Manufacturing Based on STEP*, Springer, London.
6. López de Lacalle, L. N., and Lamikiz, A., 2009, *Machine Tools for High Performance Machining*, Springer, London.

Institute Electives

IE6001E ENTREPRENEURSHIP DEVELOPMENT

Prerequisite: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 39

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.

CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.

CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.

CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification

Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management. .

Business Planning and Execution

Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies

Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

1. Kaplan, J. M., Warren, A. C., & Murthy V. (Indian Adoption), 2022, *Patterns of entrepreneurship management*. John Wiley & Sons.
2. Kuratko, D. F., 2016, *Entrepreneurship: Theory, process, and practice*. Cengage learning.
3. Barringer, B. R. 2015, *Entrepreneurship: Successfully launching new ventures*. Pearson Education India.
4. Shah Rajiv, Zhijie Gao, Harini Mittal, 2014, *Innovation, Entrepreneurship, and the Economy in the US, China, and India*, Academic Press.
5. Sundar, K., 2022, *Entrepreneurship Development*, Vijaya Nickol Imprints, Chennai.
6. Gordon, E., Natarajan, K., *Entrepreneurship Development*, Himalya Publishers, Delhi.
7. Biswas Debasish, Dey Chanchal, 2021, *Enterpreneurship Development in India*, Taylor & Francis.

ZZ6002E RESEARCH METHODOLOGY

Prerequisite: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Explain the basic concepts and types of research.
- CO2: Develop research design and techniques of data analysis
- CO3: Present research to the scientific community
- CO4: Develop an understanding of the ethical dimensions of conducting research

Exploring Research Inquisitiveness

Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation.

Data Analysis

Literature review :Tools and Techniques - Collection and presentation of data, processing and analysis of data - Descriptive statistics and inferential statistics- Measures of central tendency, dispersion, skewness, asymmetry- Probability distributions – Single population and two population hypothesis Testing - Parametric and non-parametric tests - Design and analysis of experiments: Analysis of Variance (ANOVA), completely randomized design – Measures of relationship: Correlation and regression, simple regression analysis, multiple regression – interpretation of results - Heuristics and simulation

Research Writing and Ethics

Reporting and presenting research, Paper title and keywords, writing an abstract, writing the different sections of a paper, revising a paper, responding to peer reviews.

The codes of ethics, copyright, patents, intellectual property rights, plagiarism, citation, acknowledgement, avoiding the problems of biased survey

References:

1. Foley, M., and Hall, D., 2018, *Longman advanced learner's grammar, a self-study reference & practice book with answers*, Pearson Education Limited.
2. Gerson, S. J., and Gerson, S. M., 2009, *Technical writing: Process and product*, Pearson.
3. Kirkwood, H. M. A., and M., M. C. M. I., 2013, *Hallidays introduction to functional grammar*, Hodder Education.
4. Markel, M., 2012, *Technical Communication*, Palgrave Macmillan.
5. Tuhovsky, I., 2019, *Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills*, Rupa Publications India.
6. Williams, R., 2014, *The Non-designer's Design Book*, Peachpit Press.

MS6174E TECHNICAL COMMUNICATION AND WRITING

Prerequisite: NIL

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs.

CO2: Collaborate on various writing projects for academic and technical purposes.

CO3: Combine attributes of critical thinking for improving technical documentation.

CO4: Adapt technical writing styles to different platforms.

Technical Communication

Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics

Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation

Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

1. Krishnaswamy, K.N., Sivakumar, A.I., and Mathirajan, M., 2006, *Management Research Methodology*, Pearson Education.
2. Leedy, P. D., 2018, *Practical Research: Planning and Design*, Pearson.
3. Kothari, C.R., 2004, *Research Methodology – Methods and Techniques*, New Age International Publishers.
4. Martin Mike, Schinzinger Roland, 2004, *Ethics in Engineering*, Mc Graw Hill Education.
5. Sople, Vinod V., 2014, *Managing Intellectual Property-The Strategic Imperative*, EDA Prentice of Hall Pvt. Ltd.