CURRICULUM & SYLLABI

M.TECH. Materials and Manufacturing

Effective from AY: 2025-26

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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Vision and Mission of the Institute

National Institute of Technology Warangal

VISION

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

MISSION

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

CENTRE FOR MATERIALS AND MANUFACTURING

VISION

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

MISSION

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

CENTRE FOR MATERIALS AND MANUFACTURING

List of Programs offered by the CENTER:

Program	Title of the Program
M.TECH	Materials and Manufacturing

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

CENTRE FOR MATERIALS AND MANUFACTURING

M.TECH. IN MATERIALS AND MANUFACTURING

PROGRAMME EDUCATIONAL OBJECTIVES:

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

PEO1	Analyze, design, and evaluate Materials and Manufacturing using the knowledge of mathematics, materials engineering, control system and IT tools.
PEO2	Solve engineering problems using domain knowledge of materials and Manufacturing engineering.
PEO3	Apply management principles to execute projects of interdisciplinary nature adhering to professional ethics.
PEO4	Engage in lifelong learning to adapt to the changing needs for professional advancement.

MAPPING OF MISSION STATEMENTS WITH PROGRAMME EDUCATIONAL OBJECTIVES:

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

1: Slightly 2: Moderately 3: Substantially

Program Outcomes (POs)

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

PO1	Carryout independent research/investigation and development work to solve practical problems
PO2	Write and present a substantial technical report/document
PO3	Demonstrate a degree of mastery in materials and Manufacturing engineering at a level higher than the bachelor's program
PO4	Apply knowledge of advanced materials, mechanical behavior, and control techniques for the design and analysis of manufacturing processes
PO5	Develop and validate models for materials and Manufacturing using modern engineering and IT tools to solve complex real-life problems.
PO6	Engage in lifelong learning adhering to professional, ethical, legal, safety, environmental and societal aspects for career excellence.

MAPPING OF PROGRAMME OUTCOMES WITH PROGRAMME EDUCATIONAL OBJECTIVES:

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

CURRICULUM
CENTRE FOR MATERIALS AND MANUFACTURING
M. Tech. - MATERIALS AND MANUFACTURING

I – Semester

S. No.	Course Code	Course Title	L- T- P	Credits
1	ME60001	Mechanical Behavior of materials & Failure analysis	3-0-0	3
2	MM30001	Materials Joining and Casting	3-0-0	3
3	MM30002	Industrial Heat Treatment and Phase Transformations	3-0-0	3
5		Professional Elective – I	3-0-0	3
6		Professional Elective – II	3-0-0	3
7	ME60003	Mechanical Behavior & Failure Analysis Lab	0-1-2	2
8	MM30004	Casting and Welding Lab	0-1-2	2
			Total Credits	**19**

II – Semester

S. No.	Course Code	Course Title	L-T-P	Credits
1	ME60002	Design considerations in Materials and process selection	3-0-0	3
2	MM30003	Additive Manufacturing Technologies	3-0-0	3
3		Professional Elective – III	3-0-0	3
4		Professional Elective – IV	3-0-0	3
5		Professional Elective – V	3-0-0	3
7	MM30005	Materials Characterization Lab	0-1-2	2
8	ME26008	Modelling & Analysis Lab	0-1-2	2
9	CM10001	Minor Project	0-0-0	2
			Total Credits	**21**

III – Semester

S. No	Course Code	Course Title	L-T-P	Credits
1	CM10002	Seminar and Technical writing	0-0-0	2
2	CM10003	Summer Internship/Research Experience (SIRE)	0-0-0	2
3	CM10004	Comprehensive Viva-Voce	0-0-0	2
4	CM10005	Dissertation: Part-A	0-0-0	8
		Total Credits		**14**

IV – Semester

S. No	Course Code	Course Title	L-T-P	Credits
1	CM10006	Dissertation: Part-B		12
			Total Credits	**12**

Professional Elective Courses:

Professional Elective – I		
S. No.	**Code**	**Course Title**
1	ME26027	Mechanics of Metal Forming
2	ME26028	Design and analysis of experiments
3	ME36032	AI and ML for Mechanical systems
4	ME60008	Materials for Automotive applications
5	ME60009	Manufacturing Management
6	ME36004	Industry 4.0 and IIoT
Professional Elective –II		
7	MM36007	Nanotechnology
8	MM36009	Materials for Nuclear Applications
9	MM36011	Materials for Future Vehicles
10	MM36013	Powder Processing Technology
11	MM36015	Environmental Degradation of Materials
12	MM36017	Non-Destructive Testing and evaluation
13	MM36019	Smart materials

Professional Elective – III		
S. No.	**Code**	**Course Title**
1	PH16016	Semiconductor Fabrication Technology
2	PH17032	Thin film & Vacuum Technologies
3	PH17026	Laser Applications
4	PH16018	Functional materials / Smart Interactive Materials
Professional Elective –IV		
5	ME26025	Micro and Nano Manufacturing
6	ME60010	Metrology and computer aided Inspection
7	ME36022	Supply Chain Management
8	ME26035	Finite Element Applications In Materials Processing
9	ME26026	Advanced Composite Materials and Processing
Professional Elective – V		
10	MM36006	Machine Learning for Materials Engineers
11	MM36008	Light Metals and Alloys
12	MM36010	Computational approaches in Materials Engineering
13	MM36012	Surface Engineering and coating Technology
14	MM36014	Advanced Materials Characterization
15	MM36016	Electronic and Magnetic Materials
16	MM36018	Biomaterials
17	MM36020	High Temperature Materials
18	MM36022	Aerospace Materials
19	MM36024	Welding Metallurgy of Non-Ferrous Metals

The Overall Credit Structure

Credits in Each Semester

Category	I Year, Sem – I	I Year, Sem – II	II Year, Sem – I	II Year, Sem – II	Total No. of credits to be earned
Core courses	09	06	--	--	**15**
Electives	06	09	--	--	**15**
Lab Courses	04	04	--	--	**08**
Comprehensive Viva-Voce	--	--	02	--	**02**
Summer and internship			02	--	**02**
Major Project	--	--	08	12	**20**
Minor Project		**02**			**02**
Seminar and Technical writing			**02**		**02**
Total					**66**

SYLLABI

M.Tech. Materials & Manufacturing

1st SEMESTER

ME600001 **3-0-0(3)**

Mechanical behaviour of Materials and Failure Analysis

Pre-Requisites: **Nil**

Course Outcomes:

CO1	Understand the mechanical behavior of ductile and brittle materials
CO2	Analyze Workability, creep, fatigue and fracture mechanisms for various materials
CO3	Analyze the reasons for failure of materials
CO4	Select a characterization technique to evaluate the behavior of materials

CO-PO Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: Mechanical behaviour of ductile and brittle materials, Crystal structures commonly used, imperfections in crystal structures, Basic mechanisms causing plastic deformation, Mechanics of slip in perfect crystal, Engineering stress-strain curve, Strength and ductility parameters, Plastic deformation and yield criteria, Dynamic strain aging, Effect of strain rate on flow properties, Effect of temperature on flow properties.

Fundamentals of Metal working: Classification of Forming processes, Recovery, Recrystallization and grain growth, hot working and cold working, Workability, Friction and lubrication, Ring compression test for measuring coefficient of friction.

Fatigue: Introduction, Stress cycles, The S-N curve, Effect of mean stress on Fatigue, Cyclic stress-strain curve, Low cycle fatigue, Strain-Life equation, Mechanism of Fatigue crack initiation and propagation, Effects of various parameters on Fatigue: Stress concentration, surface effects, Metallurgical variables, Effect of temperature on Fatigue.

Creep: The Creep Curve, Mechanisms of Creep deformation, Deformation Mechanism maps, Creep-Fatigue interaction.

Fracture Mechanics: Types of Fracture in metals, Theoretical cohesive strength of metals, Griffith theory of brittle fracture, Strain-Energy release rate, Fracture toughness and design, stress intensity parameter, J- integral and crack tip opening displacement as fracture criteria.

Failure analysis: Analysing Fractures, Micro mechanisms of brittle and ductile fracture, Fractography Visual Examination & Management of Applied Failure Analysis, Manage Failure Analysis, Case studies.

Learning Resources:

Textbooks:

1. Mechanical Metallurgy by Dieter, McGraw-Hill book company, 2nd Edition,2005.

2. Mechanical behaviour of materials by William F. Hosford

3. Mechanical behaviour of materials Marc Andre's Meyers, Krishan Kumar Chawla, CAMBRIDGE

University Press, 2014

Reference Books:

1. Hellen K, Introduction to Fracture Mechanics, McGraw Hill, 2002
2. J.E. Dorn, Mechanical Behaviour of Materials at Elevated Temperatures, McGraw Hill, 2000.
3. M.F Ashby and David R H Jones: Engineering Materials I: Introduction to Properties, Applications and Design,2010
4. Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, 5th Edition, Wiley, 2012.

MM30001 **3-0-0(3)**

Materials Joining and Casting

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze the non-equilibrium phase transformations in alloys.
CO-2	Analyze the influence of welding parameters on the weld performance.
CO-3	Evaluate the weld fabrication technology and quality control in welding.
CO-4	Analyze the novel and hybrid casting processes.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Welding: Different types of welding processes; heat flow, fusion zone boundaries, temperature distribution & cooling rate effect on weldment, weld solidification, weld metal nucleation, grain structure control, welding parameters, effect of travel speed, phase transformations during welding, factors influencing residual stresses, PWHT, dilution, weldability of low alloy steels, welding of stainless steels, Welding of Al, Mg, Ti and Ni alloys, welding of ceramics and composites, Joining of thin and thick sections, welding of dissimilar materials, welding defects and its remedy, weldability tests. Weld design and fabrication technology. Casting: Basics, processes, casting defects and remedies, inspection and quality control, Advanced Solidification Modelling,Specialty Casting Alloys and Processes, Defect Analysis and Process Control using advanced tools.

Learning Resources:

Text Books:

1. R.W. Heine, C.R. Loper, P.C. Rosenthal: Principles of Metal Casting, Tata McGraw-Hill Education, 2001.
2. G.E. Linnert: Welding Metallurgy, Vols I-II, 4th Ed, AWS, 1994.
3. Sindo Kou: Welding Metallurgy, 2nd Ed, John Wiley & Sons, 2002.
4. M.D. Jackson: Welding Methods and Metallurgy, Griffin, London, 1967.

Reference Books:

1. Welding Handbook, Vol 2- Welding Processes, 9th Ed, AWS, 2004.
2. ASM International Handbook Committee. ASM Handbook, Volume 15-Casting. ASM International., 2008.
3. Kenneth Easterling: Introduction to Physical Metallurgy of Welding, 2nd Ed, Butterworth Heinmann, 1992.

MM30002 **3-0-0(3)**

Industrial Heat Treatment and Phase Transformations

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the significance of phase transformations in the heat treatment industry
CO-2	Design a heat treatment process to achieve the desired property in engineering materials.
CO-3	Discuss the liquid-to-solid and solid-to-solid transformations.
CO-4	Apply the principles of physical metallurgy and phase transformations to develop novel and advanced materials.

Course Articulation Matrix:

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

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

Syllabus:

Basic of Heat treatment (HT) and its position in the industry with goals, HT cycle, Annealing, Normalising, Hardening, Tempering, age hardening, Sub-zero treatment, Austempering, Martempering, Importance of Hardenability; HT of steels, HSLA steels, Tool steels, Maraging steel, Al alloys, Ti alloys. Solid-to-Solid Transformations: Diffusional and non-diffusional solid-state transformations in ferrous and non-ferrous systems: Eutectoid, bainitic, and martensitic transformations; Order-disorder transformation; Spinodal decomposition; Transformations in advanced materials.

Learning Resources:

Text Books:

1. T.V. Rajan, C.P Sharma, Ashok Sharma, Heat Treatment: Principles and Techniques, Prentice Hall India Learning Private Limited, 2011, 2nd ed.
2. D.A. Porter, K.E. Easterling: Phase Transformations in Metals and Alloys, Van Nostrand Reinhold (International), 1989.

Reference Books:

1. P.G. Shewmon: Transformations in Metals, McGraw Hill Book Company, 1980.
2. ASM, Metals Hand Book: Heat Treating, Vol. 4, Ed., Metals Parks, Ohio.

Other Suggested Readings:

1. NPTEL Courses: https://nptel.ac.in/courses/113105023

ME60003 **0-1-2**

Mechanical behaviour & failure analysis lab

Pre-Requisites: **Nil**

Course Outcomes:

CO1	Operate mechanical testing equipment for measuring materials properties
CO2	Analyze the data obtained from mechanical testing.
CO3	Determine the fracture toughness of materials
CO4	Assess high-temperature mechanical properties of alloys

CO-PO Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Mechanical Characterizations: Hardness test, Tensile test, Compression test, Impact test, Wear and erosion test, Microhardness and indentation fracture toughness test, Fracture toughness test, Fatigue testing, failure analysis – case studies.

Learning Resources:

Textbooks:

1. R. W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, 4th Edition, John Wiley & Sons Inc., 2012.
2. M.A. Meyers and K.K. Chawla: Mechanical Behavior of Materials, Prentice Hall Inc., New Delhi, 1999.
3. T. L. Anderson: Fracture Mechanics- Fundamentals and Applications, 3rd Edition, CRC Press, 2011.
4. G. E. Dieter: Mechanical Metallurgy, McGraw-Hill, 2002

Other Suggested Readings:

1. Mechanical Behavior of Materials Laboratory Manual
2. Hardness Testing Principles and Applications-ASM International (2011), Konrad Herrman
3. ASM Handbook, Volume 20, Materials Selection and Design. Materials Park, OH: ASM International, 1990.
4. ASM Handbook, Volume 8, Mechanical Testing and Evaluation. Materials Park, OH: ASM International, 1990.
5. ASTM E18-03: Standard Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials. West Conshohocken, PA: ASTM International, 2004.

MM30004 **0-1-2**

Casting and Welding Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Demonstrate materials joining by gas welding, manual metal arc welding, submerged arc welding, resistance welding techniques.
CO-2	Demonstrate the preparation of molds and casting practice.
CO-3	Evaluate microstructure and mechanical properties of weldments and castings

Course Articulation Matrix:

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

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

Syllabus:

Welding: Preparation of weld joint using gas welding, manual metal arc welding, submerged arc welding; resistance welding; heat input calculation in arc welding; preparation of all welds tensile test specimen and characterization of weldments, study of microstructure of fusion zone, heat affected zone and base metal of the welded specimen, determine the tensile strength and ductility of a weld as per ASTM standards. Casting: Pattern making, sand testing, Melting, and casting of ferrous and nonferrous alloys. Characterization of welds and castings.

Learning Resources:

Textbooks:

1. Casting and Welding Laboratory manual, MMED, NITW
2. Cary, Howard B. and Scott C. Helzer, Modern Welding Technology. Upper Saddle River, New Jersey: Pearson Education, USA, 2005.

Reference Books:

1. Welding Handbook, Vol 2- Welding Processes, 9th Ed, AWS, 2004.
2. 4.ASM International Handbook Committee. ASM Handbook, Volume 15-Casting. ASM International,2008.

2nd SEMESTER

ME600002 **3-0-0(3)**

Design considerations in materials and process selection

Pre-Requisites: **Nil**
Course Outcomes:

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

CO-PO Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

1.Introduction: The evolution of Engineering materials, The Design process, types of design, Design tools and materials data; Function, material, shape, and process.
2.**Materials Selection**- Introduction and synopsis, the selection strategy, attribute limits and material indices, the selection procedure, computer-aided selection, the structural index, summary and conclusions, case studies.
3.**Selection of material and shape, case studies**: Introduction and synopsis, shape factors, material indices that include shape, co-selecting material and shape, summary and conclusions, case studies.
4.**Selecting candidate processes**: A strategic view, selecting candidate processes, process information maps, Computer aided process selection, Prima selection strategies, Prima categories: Casting, forming, machining processes.
5.**Designing Hybrid materials and case studies**: Introduction and synopsis, hybrids of type 1, 2, 3, 4, Ingredients of hybrid design, Summary and conclusions, case studies
6.**Materials and the environment**: The material life cycle, Material and energy consuming systems, The eco-attributes of materials, Eco-selection, Case studies.
7.**Materials and industrial design**: Introduction and synopsis, the requirements pyramid, product character, using materials and processes to create product personality, Summary and conclusions.

Learning Resources:

Textbooks:

1. M.F. Ashby: Engineering Materials, 4th Edition, Elsevier, 2005.
2. M.F. Ashby: Materials Selection in Mechanical Design, Butterworth Heinemann, 2005.
3. ASM Publication, Vol.20: Materials Selection and Design, ASM, 1997.
.

Reference Books:

1. Pat L. Mangonon: The Principles of Materials Selection and Design, Prentice Hall International, Inc.1999.
2. K.G.Swift and J.D.Booker,Process selection from Design to manufacture,BH Publication

MM30003 **3-0-0(3)**

Additive Manufacturing Technologies

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the basic principles, advantages, and challenges of additive manufacturing processes.
CO-2	Distinguish between various additive manufacturing techniques and their operational mechanisms.
CO-3	Analyze material behavior and selection criteria for additive manufacturing, focusing on metals (titanium, aluminium), ceramics, and polymers.
CO-4	Evaluate post-processing techniques and assess the quality and properties of additive manufactured components.

Course Articulation Matrix:

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

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

Syllabus:

Introduction: Overview, basic principles and advantages of additive manufacturing, classification of additive manufacturing processes, procedure of product development in additive manufacturing, challenges in additive manufacturing.

Generic AM Process: CAD model creation, STL file generation and manipulation, machine setup and build process, removal and post-processing, distinction between AM and CNC machining.

Additive Manufacturing Processes: Z-Corporation 3D printing, Stereolithography apparatus (SLA), Fused Deposition Modelling (FDM), Laminated Object Manufacturing (LOM), Ultrasonic consolidation, Material Jetting, Binder jetting

Powder Bed Fusion Processes: Selective Laser Sintering (SLS), Laser Engineered Net Shaping (LENS), Selective Laser Melting (SLM), Electron Beam Melting (EBM), powder fusion mechanisms, powder recycling, defects**.**

Direct Energy Deposition Processes: Description of DED processes; powder feeding and wire feeding; laser-based and electron beam-based deposition systems.

Materials for Additive Manufacturing: Material requirements and properties for AM processes; behavior of metals (titanium alloys, aluminium alloys), ceramics, and polymers during additive manufacturing; challenges associated with processing and post-processing of these materials**.**

Future Scope in Additive Manufacturing: Evaluation of AM-built components; applications in aerospace, biomedical, automotive, and energy sectors; emerging trends and future opportunities.

Learning Resources:

Textbooks:

1. C.K. Chua, K.F. Leong, C.S. Lim: Rapid prototyping- Principles and applications, 3rd Ed., World Scientific Publishers, 2010.
2. Gibson, I, Rosen D W., and Stucker B., Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010
3. Chee Kai Chua, Kah Fai Leong, 3D Printing and Additive Manufacturing: Principles and Applications: Fourth Edition of Rapid Prototyping, World Scientific Publishers, 2014
4. A. Gebhardt: Rapid prototyping, Hanser Gardener Publications, 2003.

Reference Books:

1. Additive Manufacturing Processes, Editor: David L. Bourell, William Frazier, Howard Kuhn, and Mohsen Seifi, ASM Handbook, Volume 24, ASM International, 2020Title of the Textbook, Author(s), Publisher, Year and Edition.
2. L.W. Liou, F.W. Liou: Rapid Prototyping and Engineering applications: A toolbox for prototype development, CRC Press, 2007.
3. A.K. Kamrani, E.A. Nasr: Rapid Prototyping- Theory and Practice, Springer, 2006.
4. P.D. Hilton, P.F. Jacobs: Rapid Tooling- Technologies and Industrial Applications, CRC Press, 2000.
5. Ian Gibson, David W Rosen, Brent Stucker: Additive Manufacturing Technologies- Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010

Online Resources:

1. https://additivemanufacturing.com/basics/
2. https://www.additivemanufacturing.media/

MM30005 **0-1-2(2)**

Materials Characterization Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Quantitatively evaluate microstructural features using image analysis techniques.
CO-2	Analyze the chemical composition of materials using SEM-EDS.
CO-3	Identify the crystal structure of materials employing X-Ray Diffraction (XRD) techniques.
CO-4	Assess the thermal properties of materials.

Course Articulation Matrix:

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

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

Syllabus:

1. Microstructural imaging and analysis using Optical Microscopy (OM).
2. Fracture surface analysis employing Scanning Electron Microscopy (SEM).
3. Microstructural characterization through Scanning Electron Microscopy (SEM).
4. Phase chemical composition analysis using SEM coupled with Energy Dispersive Spectroscopy (EDS).
5. Assessment of lattice strain and crystallite size utilizing X-Ray Diffraction (XRD).
6. Identification of phases, lattice parameter measurement, and crystal structure determination using X-Ray Diffraction (XRD).
7. Measurement of thermal properties using Differential Scanning Calorimetry (DSC).
8. Evaluation of oxidation kinetics through Thermogravimetric Analysis (TGA) or Differential Thermal Analysis (DTA).

Learning Resources:

Textbooks:

1. S Zhang, L. Li and Ashok Kumar, Materials Characterization Techniques, CRC Press, 2008.
2. David B. Williams, C.Barry Carter, Transmission Electron Microscopy, Textbook for Materials Science, Springer, 2009, 2nd Edition

Reference Books:

1. Materials Characterization Techniques Laboratory Manual

ME26008 **0-1-2(2)**

MODELLING AND ANALYSIS LABORATORY

Pre-Requisites: **Nil**

Course Outcomes:

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

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

List of Experiments:

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

Learning Resources:

1) Manuals

CM10001 **0-0-0(2)**

MINOR PROJECT

Pre-Requisites: None

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

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

Evaluation Criteria:

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

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

3rd Semester

CM10002 **0-0-0 (2)**

SEMINAR & TECHNICAL WRITING

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

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

Description:

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

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

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

Evaluation Criteria:

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

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

Evaluation Criteria-CO Mapping

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

CM10003 **0-0-0(2)**

SUMMER INTERNSHIP/RESEARCH EXPERIENCE

Pre-Requisites: None

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

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

Evaluation Criteria:

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

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

Evaluation Criteria-CO Mapping

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

CM10004 **0-0-0 (2)**

COMPREHENSIVE VIVA-VOCE

Pre-Requisites: None

Course Outcomes:

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

Course Articulation Matrix:

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

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

Description:

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

CM10005 **0-0-0(8)**

DISSERTATION PART-A

Pre-Requisites: None

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3-Substantially

Description:

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

Dissertation Evaluation:

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

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

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

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

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

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

Evaluation Criteria - CO Mapping:

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

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

4th Semester

CM10006

Dissertation-PART B

Pre-Requisites: **ME2697**

Course Outcomes

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

Course Articulation Matrix:

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

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

Description:

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

Dissertation Evaluation:

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

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

Evaluation Criteria:

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

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

Evaluation Criteria-CO Mapping:

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

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

PROFESSIONAL ELECTIVE - I

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

Mechanics of metal forming

Pre-Requisites: **Nil**

Course Outcomes:

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

CO-PO Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Introduction: Metal forming as a manufacturing process and its relationship with other processes – Classification based on type of stresses - Examples.
Description of Material properties: Tensile test, effect of properties on forming. Sheet deformation processes: Uni-axial tension, general sheet forming processes, Yield criteria, Flow rule, Yield criterion and flow rule for Anisotropic material, work of plastic deformation, isotropic and anisotropic yield functions, Bauschinger effect modelling, effective stress and strain. Sheet deformation in plane stress: strain distributions, strain diagram, deformation modes, effective stress-strain laws, principal tensions
Rolling Processes: Analysis of longitudinal strip or sheet rolling process (calculation of roll separating force, torque & power, angle of bite, maximum reduction in rolling), rolling defects
Forging processes: Metal flow in forging, Analysis of plane strain compression, Analysis of compression of circular disc
Wire Drawing Processes: Introduction, wire drawing load calculation
Deep Drawing Processes: Introduction, determination of drawing force and power in deep drawing
Extrusion Processes: Calculation of extrusion load, advances in extrusion, Defects in extrusion. Direct & indirect extrusion, impact and hydrostatic extrusion
Sheet forming: Mechanics – Flow Rules – Anisotropy - Formability of sheet, Formability tests, forming limit diagrams, strain path diagrams, Case studies
Pressing and Sintering: Workability Studies – Densification
Recent advances: Hydroforming, formability of tailor welded blanks, formability of friction stir welding sheets, incremental sheet forming, and electric assisted forming
Modelling and Simulation in Metal Forming: The plane strain compression test, FEM Model and Input Data to the Model - process simulation for deep drawing, Effective Strain and Strain-Rate, Distributions in Deformed Zones, modelling to predict the strains and formability
Case studies: Case studies on the manufacturing aspects of products using the lessons learnt and practical applications of metal forming

Learning Resources:

Textbooks:

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

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

Design and Analysis of Experiments

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Fundamentals of Experimentation: Role of experimentation in rapid scientific progress, Historical perspective of experimental approaches, Steps in experimentation, Principles of experimentation.
Simple Comparative Experiments: Basic concepts of probability and statistics, Comparison of two means and two variances, Comparison of multiple (more than two) means & ANOVA.
Experimental Designs: Factorial designs, fractional factorial designs, orthogonal arrays, standard orthogonal arrays & interaction tables, modifying the orthogonal arrays, selection of suitable orthogonal array design, analysis of experimental data.
Response Surface Methodology: Concept, linear model, steepest ascent, second order model, regression.
Taguchi's Parameter Design: Concept of robustness, noise factors, objective function & S/N ratios, inner-array and outer-array design, data analysis.

Learning Resources:

Text Books:

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

Reference Books:

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

Online Resources:

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

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

Artificial Intelligence and Machine Learning for Mechanical Systems

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Mechanical Systems evolution in the context of Industry 4.0, Key issues: Adaptability, Intelligence, Autonomy, Safety, Sustainability, Interoperability, Flexibility of Mechanical Systems.
Introduction of Statistics; Descriptive statistics: Central tendency measures, Dispersion measures, data distributions, center limit theorem, sampling, sampling methods; Inferential Statistics: Hypothesis testing, confidence level, degree of freedom, P-value, Chi-square test, ANOVA, Correlation V's Regression, Uses of Correlation and regression.
Artificial Intelligence: Brief review of AI history, Problem formulation: Graph structure, Graph implementation, state space representation, search graph and search tree, Search Algorithms: random search, Depth-first, breadth-first search and uniform-cost search. Heuristic: Best first search, A* and AO* algorithm, generalization of search problems. Ontology; Fuzzy; Meta-heuristics.
Machine Learning: Overview of supervised and unsupervised learning; Supervised Learning: Linear Regression, Non-linear Regression Model evaluation methods, Logistic Regression, Neural Networks; Unsupervised Learning: K-means clustering, C-means Clustering. Convolutional Neural Networks (CNN), Pooling, Padding Operations, Interpretability in CNNs, Limitations in CNN. Cases with respect to different mechanical systems.
Introduction to Raspberry Pi; Installation of Raspbian OS on Raspberry Pi; Controlling LED using Raspberry Pi; Integrating IR Sensor with Raspberry Pi; Controlling LED with IR Sensor; Integrating Temperature and amp; Humidity Sensor with Raspberry Pi read Current Environment Values, Collecting the sensor data using Raspberry Pi; Matlab toolboxes - Simulink, Mechanical Systems implementation: From features to software components, Mapping software components to ECUs.

Learning Resources:

Text Books:

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

ME60008 **3-0-0 (3)**

Materials for automotive applications

Pre-Requisites: **Nil**

Course Outcomes:

CO1	Understand the properties and applications of advanced materials in vehicle design.
CO2	Explain the role materials in improving vehicle performance, safety, and sustainability.
CO3	Describe the properties of the material required for automotive applications
CO4	Analyze the structure, property, and processing relationship for metallic and non-metallic materials for automotive applications.
CO5	Suggest materials for automobile structural and functional components.

CO-PO Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Overview of the automotive industry's evolution and future trends, importance of materials in vehicle design and performance.

Classification of materials used, lightweight materials: strategies for reducing weight, impact on emission and fuel efficiency.

Automotive Components & Material Selection, Selection of materials for different components of automobiles.

Classes of materials and their properties: metals, alloys, polymers, ceramics, composites, body materials: aluminum alloys, steels, special steels, magnesium, sandwich materials.

Metallic materials: AHSS, UHSS, aluminum, magnesium and titanium alloys in vehicles.

Polymer composites: types of polymers and reinforcements, applications of PMCs vehicles interior and structures.

Smart materials: definition, shape memory alloys, piezoelectric, self-healing, meta-materials and their potential applications.

Materials, energy storage materials: batteries, supercapacitors,

Thermal management materials: phase change materials, thermal interface materials.

Green materials: biodegradable and recyclable materials, natural fiber composites, materials for structural health monitoring, case studies.

Light-weighting automobiles, future vehicles and materials, materials for electric vehicles, materials selection in design.

Learning Resources:

Textbooks:

G Davies, Materials for automobile bodies, Butterworth-Heinemann Ltd; 2ed, 2012
Brain Cantor, P Grant, Automotive Engineering, Lightweight, Functional, and Novel materials, Taylor & Francis 1 ed., 2008.
Rana, Radhakanta, and Shiv Brat Singh. Automotive steels: design, metallurgy, processing, and applications. Woodhead Publishing, 2016.
4. Jason Rowe (Ed): Advanced Materials in Automotive Engineering, Woodhead Publishing Limited, 2012.

Reference Books:

Jason Rowe, Advanced Materials in Automotive Engineering, Woodhead Publishing, 2012
Geoffrey Davies: Materials for Automobile Bodies, Elsevier, 2012.
Brian Cantor, P. Grant, C. Johnston (Eds): Automotive Engineering- Lightweight, Functional, and Novel Materials, CRC Press, 2007.
Hiroshi Yamagata: The Science and Technology of Materials in Automotive Engines, Woodhead Publishing Limited, 2005.
W.D. Callister: Material Science and Engineering -An Introduction, Wiley – Eastern, 2006

Other Suggested Readings:

Journal articles and research papers from sources such as SAE International, and the Journal of Automotive Engineering.
Kenneth G. Budinski, Michael K. Budinski Engineering Materials, Prentice-Hall, 9th Ed., 2009.

ME60009 **3-0-0 (3)**

MANUFACTURING MANAGEMENT

Pre-requisites: **NIL**

Course Outcomes:

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

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

Course Articulation Matrix:

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

Syllabus:

Competitive priorities and manufacturing strategy: Introduction, Historical perspective of manufacturing management, Competitive priorities and operational strategy, Functional area strategy and Capability, Case Study.
Demand Forecasting: Introduction, Quantitative Methods introduction, Time series and moving averages method, Exponential Smoothing method, Regression Analysis Method, Qualitative Methods.
Facility Design: Introduction and History, Product design and process selection, Capacity planning, Plant location and Plant layout.
Inventory control: From EOQ to ROP, Independent Demand Inventory control & Economic Order Quantity (EOQ), Dynamic lot sizing, Statistical inventory control models.
The MRP crusade: History, Need, Evolution, Dependent Demand & Material Requirement Planning (MRP), Structure of MRP system, MRP Calculations.
The JIT revolution: Just-in-Time System: origin & goals, Characteristics of JIT Systems, Continuous Improvement, The Kanban System, Strategic Implications of JIT System.
Production Planning and Control: Shop floor control, Production scheduling, Aggregate planning, Aggregate and workforce planning.
Supply Chain Management: Introduction to Supply Chain Management, Decision phases in a supply chain, Process views of a supply chain: push/pull and cycle views, Achieving Strategic fit, Expanding strategic scope.

Textbooks:

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

Reference Books:

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

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

Industry 4.0 and IIoT

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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

Sensors and Actuators

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

Modelling, Analysis of Mechatronics Systems

Basics of System Modelling: LTI and LTV systems, Need for modelling, Types of modelling, Steps in modelling, Building blocks of models, Modelling of one and two degrees of freedom systems, Modelling of Electro-mechanical systems, Mechanical Systems, Fluid systems, Thermal systems; Dynamic Responses, System Transfer Functions, State Space Analysis and System Properties, Stability Analysis using Root Locus Method, Stability Analysis using Bode Plots, PID Controllers. Programmable Logic Controllers (PLCs): Architecture, Number Systems Basics of PLC Programming, Logic gates, Timers and Counters, Communication among HMI, PLC, SCADA, Fault diagnostics / troubleshooting. Application on real time industrial automation systems.

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

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

IIoT & Cloud Application Development: Solution framework for IoT applications- Implementation of Device integration, Data acquisition and integration, Cloud service and platforms: Commercial clouds

(such as Amazon elastic compute cloud, Google Compute engine, Windows Azure), Storage services, database services, application services, content delivery services, analytics services.
Case Studies: IIoT & Cloud based case studies and mini projects based on Industrial automation, Transportation, Agriculture, Healthcare, Home Automation.

Learning Resources:

Text Books:

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

Reference Books:

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

Online Sources:

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

PROFESSIONAL ELECTIVE - II

MM36007 **3-0-0 (3)**

Nanotechnology

Pre-Requisites: **None**

Course Outcomes:

CO1	Discuss the significance, properties, and applications of nanomaterials
CO2	Distinguish various synthesis techniques for the preparation of nanomaterials
CO3	Appraise the effect of size reduction on functional properties of materials
CO4	Select suitable nanomaterials for advanced applications

Course Articulation Matrix:

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

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

Syllabus:

Significance, properties and applications nanomaterials, carbon nano structures, nano indentation, super plastic behaviour of nanomaterials, Ceramic nanosystems, quantum confinement, effect of size reduction on optical, electrical, electronic, mechanical, magnetic and thermal properties of materials, nano electronics, Nano fluidics, NEMS, photonic crystals, biomimetic nano structures.

Learning Resources:

Text Books:

1. B S Murty et. al.: Textbook of Nanoscience and Nanotechnology, Universities Press (India) Private Limited 2013.
2. Sulabha K. Kulkarni: Nanotechnology Principles and Practices, Capital Publishing Company, 2007.
3. Massimilano Di Ventra, S. Evoy, James R. Heflin Jr: Introduction to Nanoscale Science and Technology, Springer, 2009.
4. Charles P. Poole Jr., Frank J. Owens: Introduction to Nanotechnology, Wiley India, New Delhi, 2010.

Reference Books:

1. Jack Uldrich, Deb Newberry: Next Big Thing Is Really Small: How Nanotechnology Will Change the Future of Your Business.
2. H. Hosono, Y. Mishima, H. Takezoe, K.J.D Mackenzie: Nanomaterials- From Research to Applications, Elsevier, 2008.

Other Suggested Readings:

1. www.nano.gov
2. www.science.doe.gov/nano
3. www.nnin.org

MM36009 **3-0-0 (3)**

Materials for Nuclear Applications

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the types of materials used in nuclear reactors and the criteria for their selection.
CO-2	Analyze radiation damage mechanisms and their effects on the properties of materials.
CO-3	Evaluate the performance of structural, fuel, and moderator materials under nuclear environments.
CO-4	Assess recent developments in advanced nuclear materials for fission and fusion reactors.

Course Articulation Matrix:

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

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

Syllabus:

Overview of nuclear reactors: fission and fusion systems; Fuel materials (UO_2, MOX, ThO_2), cladding materials (Zircaloy, stainless steels, advanced ferritic/martensitic steels), moderator and reflector materials (graphite, heavy water, beryllium).
Radiation-matter interaction: Displacement damage, transmutation, helium and hydrogen effects. Point defects, dislocation loops, void swelling, irradiation creep, and embrittlement.
Materials for fusion reactors: First wall and blanket materials, divertor materials, low activation materials, tungsten, and silicon carbide composites.
Characterization of radiation damage: Techniques such as Transmission Electron Microscopy (TEM), Positron Annihilation Spectroscopy (PAS), Nanoindentation.
Recent advances in nuclear materials: Oxide Dispersion Strengthened (ODS) steels, self-healing materials, and accident-tolerant fuels.

Learning Resources:

Text Books:

3. G. S. Was, Fundamentals of Radiation Materials Science: Metals and Alloys, Springer, 2016.
4. John R. Lamarsh and Anthony J. Baratta, Introduction to Nuclear Engineering, Prentice Hall, 2001.

Reference Books:

3. F. A. Garner, Radiation Damage in Austenitic Steels, Springer, 1994.
4. W. D. Callister, Materials Science and Engineering, Wiley, 2020, 10th Edition (selected chapters).

MM36011 **3-0-0 (3)**

Materials for Future Vehicles

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the evolving material requirements in future automotive, aerospace, and electric vehicles.
CO-2	Compare traditional and emerging materials in terms of strength, weight, and sustainability.
CO-3	Evaluate material selection strategies for light weight, energy efficient, and safety enhanced vehicles.
CO-4	Analyze case studies of material applications in next-generation vehicles (e.g., EVs, hydrogen vehicles, UAVs).

Course Articulation Matrix:

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

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

Syllabus:

Overview of the future vehicle ecosystem: electric vehicles (EVs), hybrid vehicles, autonomous vehicles, hydrogen fuel cell vehicles, and UAVs; Materials challenges and opportunities.

Lightweight materials: Advanced high-strength steels (AHSS), aluminum alloys, magnesium alloys, titanium alloys, composites, and polymeric materials.

Emerging materials: Nanostructured materials, graphene, 2D materials, and high-entropy alloys.

Battery and energy storage materials: Lithium-ion, solid-state, sodium-ion, and hydrogen storage materials.

Materials for safety, thermal management, and sustainability: Crash-resistant materials, phase change materials (PCM), recyclable and bio-based materials.

Learning Resources:

Textbooks:

1.M. F. Ashby, Materials Selection in Mechanical Design, Butterworth-Heinemann, 2016, 5th Edition.

2.S. R. Bull, Materials for Energy Efficiency and Thermal Comfort in Buildings, Woodhead Publishing, 2010, 1st Edition. (Selected chapters)

Reference Books:

5. De Moor, Emmanuel. "Advanced high-strength sheet steels for automotive applications." High-Performance Ferrous Alloys (2021): 113-151.
6. C. C. Koch, Nanostructured Materials: Processing, Properties, and Applications, William Andrew Publishing, 2006, 2nd Edition.

MM36013 **3-0-0 (3)**

Powder Processing Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain various powder production, and characterization techniques
CO-2	Compare and appraise powder processing techniques
CO-3	Appraise the need for powder processing in the fabrication of special engineering components
CO-4	Evaluate the fabrication processes of special engineering components by powder metallurgy

Course Articulation Matrix:

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

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

Syllabus:

Basic steps of powder metallurgy, Synthesis of Nanocrystalline powder through Chemical Synthesis & Mechanical Alloying, chemical synthesis and atomization of powder, characterization of powder, powder compaction, conventional and Modern Sintering Technique (HIP, SPS, Laser Sintering, Microwave Sintering), sintering of production of filters, self-lubricating bearings, gears, friction parts, electrical materials, carbide tools, tungsten filament, bioceramics, powder metallurgy of superalloys and stainless steel, dispersion strengthened materials, application of powder metallurgy in Indian industries.

Learning Resources:

Text Books:

5. R. M. German, Powder Metallurgy & Particulate Materials Processing, MPIF, 2005, 3rd Edition.
6. Upadhyaya and G S Upadhyaya, Powder Metallurgy, Universities Press, 2011, 1st Edition.

Reference Books:

7. P. C. Angelo and R. Subramanian: Powder Metallurgy- Science, Technology and Applications, PHI, 2008, 1st Edition.
8. J. S. Hirschhorn: Introduction to Powder Metallurgy, American Powder Metallurgy Institute, 1976, 1st Edition

MM36015 **3-0-0 (3)**

ENVIRONMENTAL DEGRADATION OF MATERIALS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze various mechanisms of material degradation across different environments
CO-2	Evaluate Degradation mechanisms from thermodynamic principles.
CO-3	Understand the techniques to study and analyze material degradation
CO-4	Evaluate failure modes and recommend mitigation methods based on environmental factors

Course Articulation Matrix:

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

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

Syllabus:

Degradation economics; types of material degradation: electrochemical degradation mechanisms, high-temperature corrosion and oxidation behavior, chemical and physical ageing processes in polymers and composites; degradation of reinforced concrete due to carbonation, chloride attack, and rebar corrosion; biofouling and biodegradation mechanisms affecting structural materials; erosion corrosion influenced by environmental variables such as temperature, flow rate, and pH; cavitation erosion, fretting corrosion, intergranular corrosion; corrosion behavior of ceramic materials under various thermal and chemical environments; laboratory assessment techniques for material degradation including linear polarization resistance (LPR) methods, Tafel extrapolation for corrosion rate determination, oxidation studies through thermogravimetric methods, and analysis using free energy-temperature (Ellingham) diagrams; corrosion control strategies through appropriate material selection and design optimization, protective coatings (metallic, ceramic, polymeric), corrosion inhibitors and passivators for chemical protection, cathodic and anodic protection systems.

Learning Resources:

Textbooks:

1. Myer Kutz, *Handbook of Environmental Degradation of Materials*, William Andrew Publishing, 2005.
2. Denny A. Jones, *Principles and Prevention of Corrosion*, Pearson, 2014.
3. Mars G. Fontana, *Corrosion Engineering*, Tata McGraw-Hill, 2005.
4. Raj Narayan, *An Introduction to Metallic Corrosion and Protection*, Oxford University Press, 1983.
5. Recent review papers from journals like *Corrosion Science*, *Materials Degradation*.

Reference Books:

1. ASM Metal Handbook, Vol 13A- Corrosion- Fundamentals, Testing & Protection, ASM, 2004.
2. Einar Bardal, Corrosion and Protection, Springer, 2004.

Online Resources:

1. Nptel

MM36017 **3-0-0 (3)**

Non-Destructive Testing and Evaluation

Pre-Requisites: **Engineering Physics**

Course Outcomes:

CO-1	Demonstrate understanding of the principles and operational procedures of major NDT techniques.
CO-2	Select suitable NDT methods for inspection based on material type and defect nature.
CO-3	Interpret results from NDT methods to detect and characterize defects in materials and components.
CO-4	Evaluate material integrity and performance using advanced NDE techniques and signal analysis.
CO-5	Integrate NDE results into material evaluation processes for quality assurance, life prediction, and structural health monitoring.

Course Articulation Matrix:

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

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

Syllabus:

Introduction to NDT and NDE: Definitions, importance, and classifications. Visual Inspection and Optical Methods: Basic techniques, tools, and applications. Radiographic Testing (RT): X-rays, Gamma rays, film and digital radiography, image interpretation. Ultrasonic Testing (UT): Principles, equipment, defect characterization, advanced UT techniques (phased array, TOFD). Magnetic Particle Testing (MPT) and Eddy Current Testing (ECT): Theory, techniques, and limitations. Penetrant Testing (PT): Liquid penetrant testing methods and applications. Acoustic Emission Testing: Basics and structural health monitoring applications. Techniques for analyzing signals from NDE equipment (like ultrasonic, acoustic emission) to detect and classify defects. NDE in structural Health Monitoring (SHM): use of sensors and real-time monitoring to evaluate the ongoing health of structures like bridges, aircraft, and pipelines. Probability of Detection (POD) and Reliability Analysis: statistical evaluation of the effectiveness of NDE techniques and their ability to consistently detect defects. Advanced Imaging Techniques in NDE: computed tomography (CT), 3D ultrasonic imaging. Machine Learning and AI Applications in NDE. Codes, Standards, and Certification: ISO, ASTM, ASME standards for NDT/NDE.

Learning Resources:

Textbooks:

1. Non-Destructive Examination and Quality Control, ASM International, Vol.17, 9th edition (1989)
2. J. Prasad and C. G. K. Nair, Non-Destructive Test and Evaluation of Materials, Tata McGra Hill Education, 2nd edition (2011).
3. B. Raj, T. Jayakumar and M. Thavasimuthu, Practical Non Destructive Testing, Alpha Science International Limited, 3rd edition (2002).

4. T. Tangachari, J. Prasad and B.N.S. Murthy, Treatise on non-destructive testing and evaluation, Navbharath Enterprises, Vol.3, (1983).

Reference Books:

1. C. Hellier, Handbook of NonDestructive Evluation, McGraw-Hill Professional, 1st edition (2001).
2. J. Thomas Schmidt, K. Skeie and P. MacIntire, ASNT Non Destructive Testing Handbook: Magnetic Particle Testing, American Society for Nondestructive Testing, American Society for Metals, 2nd edition (1989).
3. V. S. Cecco, G. V. Drunen and F. L. Sharp, Eddy current Manual: Test method, Vol.1, Chalk River Nuclear Laboratories (1983).
4. B.P.C. Rao, Practical Eddy Current Testing, Alpha Science International Limited (2006).
5. N. A. Tracy, P. O. Moore, Non-Destructive Testing Handbook: Liquid Penetrant Testing, Vol. 2, American Society for Nondestructive Testing, 3rd edition (1999).

Online courses:

https://onlinecourses.nptel.ac.in/noc20_mm07/preview
https://onlinecourses.nptel.ac.in/noc23_me47/preview

MM36019 **3-0-0 (3)**

Smart Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend operational principles of optical fibres, magneto/electro rheological fluids
CO-2	Evaluate shape memory materials for strategic applications
CO-3	Suggest materials for energy harvesting applications
CO-4	Select materials for sensor/actuator applications in smart structures

Course Articulation Matrix:

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

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

Syllabus:

Introduction: Smart responses from nature, Classification of smart materials, Dependence of structure on material behavior, Sensing and actuation, Examples and applications. Piezoelectric and Magnetostrictive Materials: Piezoelectric effect, Structure and processing of piezoelectric ceramics, Polymer piezoelectric, Composites, Electro strictive materials, Applications, Magnetostrictive materials, Magnetostrictive effects for sensing and actuation, Hybrid sensors, Applications.
Shape memory materials: Shape memory alloys (SMAs), Shape memory effect and phase changes, Phase transformation process for SMAs, Types of SMAs, Super elasticity, SMA properties and Processing, SMA fibers in composites, Applications of SMAs – aerospace, automotive, medical and construction, Challenges in SMAs, Smart memory ceramics, Mechanisms of smart recovery in ceramics.
Magneto/electro rheological fluids and optical fibers: Magneto rheological (MR) fluids, MR vs ferro fluids, Applications – damping and dissipation, Electro rheological (ER) fluids, Giant electro rheological (GER) fluid and its applications, Advantages and disadvantages, Optical fibers, Fiber optic total internal reflection, Fiber optic sensors, Intrinsic and extrinsic fiber optic sensors, Applications, and advantages.
Smart Structures: Need for smart structures, Concept of smart structure, Integration of functions, sensor / actuator and control mechanisms, Smart structure classifications, Applications – aerospace, defence, automotive, industrial, medical, civil/construction.

Learning Resources:

Text Books:

1. M.V. Gandhi, B.S. Thompson, Smart Materials and Structures, Chapman & Hall, 1992.
2. L. Meirovitch, Dynamics and Control of Structures, John Wiley,1992.
3. D.I. Arun, P. Chakravarthy, R. Arockia Kumar, B. Santhosh, Shape Memory Materials, CRC Press, 2018.

PROFESSIONAL ELECTIVE - III

PH16016 **3-0-0(3)**

Semiconductor Fabrication Technology

Pre-Requisites: **None**

Course Outcomes:

CO1	Understand the fundamental attributes of semiconductors
CO2	Appreciate and analyse the characteristics of semiconductors
CO3	Identify suitable semiconducting material for a fabrication process
CO4	Evaluate the chosen semiconductor for a desired application

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Detailed Syllabus:

Introduction to semiconductors: Band formation in semiconductors - direct and indirect bandgap semiconductors - concept of holes - carrier concentration - effective mass - heavy and light mass carriers – Fermi Level - doping in semiconductors – Thermal Diffusion – Ion Implantation - band tunability - heavily doped semiconductors - excitons – metallic contacts in semiconductors - PN diodes.

Characteristics of Semiconductors: Thermal motion of carriers, carriers under electric field, mobility and drift current, diffusion of carriers, general expression for current in a semiconductor, PN junction electrostatics, fixed and free charge, electric field at the junction, energy band diagram of a PN junction - PN junction under applied bias, band-bending under applied bias, ideal diode equation.

Materials and fabrication Techniques: Silicon – single crystal, nanocrystalline and amorphous silicon, Siemens Process - compound semiconductors – II-V and III-V compounds, synthesis, and crystal growth techniques – Czochralski crystal pulling technique, floating zone technique – Wafer slicing – Wafer Polishing - Wafer cleaning – Wet and Dry cleaning - RCA and Piranha Cleaning – Wafer Quality measurements - Steps involved in photolithography - etching: wet, dry, Anisotropic etching

Semiconductor devices: Light-matter interaction - Optical absorption of Silicon, PIN photodetectors, Photovoltaic cells - open circuit voltage and short circuit current - light emitting devices: LEDs and their luminescence efficiency, heterostructures, double heterostructure and population inversion, Semiconductor diode lasers, light-intensity characteristics and threshold current, scaling trends: Moore's law, short channel effects, e-beam lithography and nano-imprint.

Learning Resources:

Text Books:

1. Introduction to Solid State Physics, Charles Kittel, John Wiley & Sons, Inc., 2005.
2. Semiconductor Devices, S. M. Sze, M. K. Lee, John Wiley & Sons, INC., 2010.
3. Electronic properties of materials: An introduction for engineers, Rolf E Hummel, Springer New York, NY, 2011.
4. The growth of single crystals, Laudise, R. A., 1970, Publisher - Englewood Cliffs, N.J., Prentice-Hall Collection

Reference Books:

1. Elementary Solid-State Physics, M. Ali Omar, Pearson Publications, fourth edition, 2005.
2. Solid State Physics by A. J. Dekker, Macmillan, seventh edition, India, 2015.
3. Solid State Physics, by. S. O. Pillai, New Age International Pvt. Ltd, seventh edition 2015.

PH17032 **3-0-0 (3)**

Thin Films and Vacuum Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand generation and monitoring of high vacuum using pumps and gauges
CO-2	Explain the influence of growth process on the properties of thin films
CO-3	Identify vacuum related flaws in standard physical vapour deposition units
CO-4	Select appropriate PVD/CVD technique for the deposition of thin films
CO-5	Determine grain size, texture coefficient, sheet resistance, thickness and band-gap of thin films

Course Articulation Matrix:

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

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

Syllabus:

Fundamentals of Vacuum science: Fundamentals of Vacuum-types of flow-Viscous, Lamellar and molecular fluid region, Conductance, Mean-free path, Medium, High and Ultra-high vacuum pumps, (Working principle of Rotary pump, Diffusion pump, Turbo-molecular pump and Ti sublimation pump). Vacuum Measuring Gauges-principle, calibration and electronics read out (Pirani gauge and Penning gauge). Types of O-Rings, valves and clamps – Thermal vacuum bake-out.

Introduction to Thin Films: Film Formation - Types of Growth Modes (Volmer - Weber, Frank - van der Merwe, Stranski-Krastanov), Factors influencing film growth and quality, Types of Films – Polycrystalline, Epitaxial growth, textured growth - Substrate cleaning procedure - Thickness measurement techniques (quartz micro-balance, stylus profiler and optical interference techniques). Film adhesion, abrasion and hardness.

Thin films Coating Techniques: Physical coating techniques-Thermal Evaporation (Working principle and Standard Operational Procedure), e-Beam Evaporation, Sputtering (Ion beam sputtering, RF and DC Magnetron Sputtering), Pulsed Laser Deposition, Clean room and architecture of modern-day coating plants. Chemical coating techniques-Spin coating, Sol-gel dip coating, Spray Pyrolysis-Viguie Spitz mechanism, Electro-deposition, Molecular Beam Epitaxy, CVD and MOCVD processes and systems.

Characterization of Thin films: Texture coefficient, Standard deviation and grain size (from grazing incidence XRD), Stress and strain in thin films, Sheet resistance measurement of thin films (Four Probe method), Surface composition, morphology and roughness (using SEM and AFM and appropriate software), Optical transmittance, reflectance and Band gap estimation (from UV-Vis data), Electrical transport property by Hall effect measurement.

Learning Resources:

Text Books:

1. Milton Ohring, Materials Science of Thin Films, Academic Press, San Diego, 2002.
2. Krishna Seshan (Ed.) Handbook of Thin-Film Deposition Processes and Techniques, Noyes Publications-William Andrew Publishing, Norwich, New York, U.S.A., 2002.

Reference Books:

1. Handbook of Thin Film Technology- Leon –Imaissel & Reihard Glang –Mc Graw – Hill Book Company -1970
2. D.M. Hoffman, B. Singh, J.H. Thomas, Handbook of Vacuum Science and Technology, Academic Press 1998.
3. Mironov V. L.: Fundamentals of Scanning Probe Microscopy. Tekhnosfera, Moscow 2004.

Other Suggested Readings:

1. https://www.svc.org/Education/SVC-Education-Program.cfm
2. http://technology.niagarac.on.ca/courses/phtn1432/#notes

PH17026 **3-0-0 (3)**

Laser and Applications

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the theory and working of CO2, Rare earth doped-YAG, Excimer and Ruby lasers and their applications in material processing
CO-2	Explain LIDAR and its applications in atmospheric studies
CO-3	Select inertial navigation using ring laser gyro.
CO-4	Identify laser guided weapons and electro-optic surveillance systems

Course Articulation Matrix:

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

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

Syllabus:

Quantum Theory of Laser: Radiative and Non-radiative decay of excited state atoms – Emission Broadening and linewidth – Radiation and Thermal equilibrium – Conditions for laser action – Laser Oscillation above threshold - Laser Amplifiers – Requirements for obtaining population inversion – Rate Equations for three and four level systems – Laser pumping requirements – Laser Cavity modes – Stable resonators – Gaussian beams- Special Laser Cavities – Q-switching and Mode locking – Generation of ultrafast Optical pulses- Pulse compression

Lasers in Atmospheric Studies- Laser for detection and ranging- LIDAR: applications-Doppler wind LIDAR, Differential Absorption LIDAR for water vapour monitoring.

Laser application in material processing: CO2, YAG, Excimer, Ruby lasers-[material processing, Cutting, Welding, drilling, micro machining] – Interaction of laser radiation with matter, Heat Flow Theory, Process characteristics etc.

Lasers for space applications: free space communication, laser propulsion, laser ignition, Optical Rotation sensors and their applications for space navigation: Sagnac Interferometers and their applications for space, Ring Laser gyros- Laser Resonator Design, Laser Frequency stabilization techniques, Ring resonator – stable and unstable and their application in Ring Laser Gyros.

Laser Target Designators and Laser-Guided Weapons: Laser Guidance, Laser target designators, laser guided missiles, laser guided bomb. Laser beam riding of missiles. Laser & electro- optic surveillance systems, IR guidance.

Learning Resources:

Text Books:

1. Laser Principles, Types & Applications, K R Nambiar, New Age International, 2006.
2. Lasers: Theory and Applications, A K Ghatak and K Thyagarajan, Springer publications, 2nd edtion,2010

Reference Books:

1. Quantum Electronics, Amnon Yariv, John Wiley, 2nd edition,1989.
2. Lasers, Siegman, Anthony E, California/University of Science Books, 1986.
3. Physics of gas lasers, Bennett, W R/Montroll, Elliot W, New York/Gordon and Breach,1977.

Other Suggested Readings:

1. https://nptel.ac.in/courses/104/104/104104085/
2. https://nptel.ac.in/noc/courses/noc19/SEM1/noc19-cy13/

PH16018 **3-0-0 (3)**

Functional and Interactive Materials

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the fundamentals and classify functional materials
CO-2	Understand different types of stimuli-responsive materials and their mechanisms of action
CO-3	Acquire basic knowledge of fabrication techniques of simple functional materials
CO-4	Select suitable materials for sensors, actuators, energy and biomedical devices applications
CO-5	Synthesize two standard functional materials by at least two simple techniques

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Definition of Functional Materials - Interactive Materials: Fundamentals and Classification - Passive vs. Active Materials: Comparison and Mechanisms - Structure-Property-Function Relationships in Functional Materials - Working principles: Adaptivity, Responsiveness, Self-healing.

Mechanisms and Types of Smart Materials: Electrical Responsive Materials: Piezoelectricity, Pyroelectricity, and Ferroelectricity - Magnetic Responsive Materials: Magnetostriction and Magnetoelectric Coupling - Photo responsive Materials: Photomechanical and Photochromic Systems - Thermoresponsive Materials: Phase Change Materials and Thermal Actuators - pH-Responsive and Chemically Responsive Systems: Smart Hydrogels and Self-Healing Polymers - Liquid Crystal Responsive Materials and their Mechanisms.

Design Strategies and Synthesis: Role of defects, doping, interfaces, and nano structuring for inducing functionality Synthesis routes: Sol-Gel, Hydrothermal, and Solvothermal Methods - Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD) Techniques - Electrodeposition, Electrospinning, and Combustion Synthesis for Responsive Materials.

Fabrication and Applications: Thin-Film Fabrication Techniques: Spin Coating, Dip Coating, Doctor Blade Coating, and Vacuum Assisted Filtration - Nanocomposite Fabrication: Integration of MXenes, Graphene, CNTs, and Quantum Dots - Processing of Flexible, Stretchable, and Wearable Materials - Sensors (Pressure, strain, temperature and gas sensors) and Actuators (soft and elastomer actuators) - Energy Harvesting (piezoelectric and triboelectric nanogenerators) and Storage Devices.

Learning Resources:

Text Books:

1. C. Suryanarayana and A. Inoue, Functional Materials, Elsevier, 2020.
2. Ashutosh Tiwari, Advanced Functional Materials, Wiley-Scrivener, 2014
3. J. T. S. Irvine, D. Neagu, Functional Materials for Sustainable Energy Applications, Royal Society of Chemistry, 2014
4. Deborah D.L. Chung, Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications, World Scientific, 2021
5. Martin E. Rogers, Functional Materials: Properties, Performance and Evaluation, CRC Press, 2016

Reference Books:

1. Vijay K Varadan, Vinoy K J and Gopalakrishnan S, Smart Material Systems and MEMS Design, Development and Methodologies, John Wiley & sons Ltd., 2006
2. Gandhi M.V. , Thompson B.S , Smart Materials and Structures, Kluwer Academic Publishers, 1992
3. M. Willander and O. Nur, Smart Materials: Fundamentals, Properties and Applications, Wiley-VCH, 2016.
4. G. Srinivasan, Smart Materials, Cambridge University Press, 2021.

Other Suggested Readings:

1. https://www.stem.org.uk/resources/elibrary/resource/447150/smart-materials
2. https://discovermaterials.co.uk/resource/smart-materials/

PROFESSIONAL ELECTIVE - IV

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

Micro and nano manufacturing

Pre-Requisites: **NIL**

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 -Substantially

Detailed Syllabus:

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

Nano-materials Synthesis and Processing: Methods for creating Nanostructures; Processes for producing ultrafine powders- Mechanical grinding; Wet Chemical Synthesis of nano-materials- sol-gel process, Liquid solid reactions; Gas Phase synthesis of nano-materials.

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

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

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

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

Learning Resources:

Textbooks:

MEMS and Microsystems: Design and Manufacture, Tai-Ran Hsu, McGraw- Hill, 2008

Fundamentals of Microfabrication: The Science of Miniaturization, Marc Madou, CRC Press, 2002, Second Edition.

Microfabrication and Nano manufacturing, Mark James Jackson, CRC Press, 2005.

Reference Books:

Introduction to Nanoscience and Nanotechnology, Gabor L. Hornyak, H.F Tibbals, Joydeep Dutta & John J Moore, CRC Press, 2009.

Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, Ray F. Egerton, Springer, 2005.

Thermal Analysis of Materials, Robert F Speyer, Marcel Dekker Inc. New York, 1994.

Elements of X-Ray Diffraction, B.D. Cullity, Prentice Hall, 2002, 3rd edition.

ME60010 **3-0-0(3)**

Metrology and computer aided inspection

Pre-requisites: NIL

Course Outcomes:

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

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

Course Articulation Matrix:

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

Syllabus:

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

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

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

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

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

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

Learning Resources:

Text Books:

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

Reference Books:

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

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

Supply chain management

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

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

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

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

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

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

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

Learning Resources:

Text Books:

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

Designing and Managing the Supply Chain - Concepts Strategies and Case Studies, David Simchi-Levi, PhilpKamintry and Edith Simchy Levy, Tata-McGraw Hill, 2000, 2nd Edition.

Managing Supply Chains A Logistics Approach', John J Coyle, Cengage Learning, 2013, 9th Edition

Modeling the Supply Chain', Jeremy F Shapiro, Cengage Learning, 2007, 2nd Edition.

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

Finite element applications in materials processing

Pre-Requisites: **None**

Course Outcomes:

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

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

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

FEA in 2 D problems, Interpolation in two dimensions, natural coordinates, Isoparametric representation, Concept of Jacobian. Finite element formulation for plane stress plane strain and axi-symmetric problems; Triangular and Quadrilateral elements, higher order elements, subparametric, Isoparametric and superparametric elements. Formulation of plate bending elements using linear and higher order bending theories, Shell elements. Exercises on structural, flow and heat transfer problems.

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

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

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

Learning Resources:

Textbooks:

Henry S Valberg, Applied Metal Forming: Including FEM Analysis, Cambridge Press. 2010

Nam Ho Kim, Introduction to Non-Linear Finite Element Analysis, 2015, Springer.

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

Reference Books:

S S Rao, *The Finite Element Method in Engineering*, 4th Edition, Elsevier 2007.

Reddy, J.N., *Finite Element Method in Engineering*, Tata McGraw Hill, 200

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

Advanced Composite Materials and Processing

Pre-Requisites: **None**

Course Outcomes:

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

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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

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

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

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

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

Learning Resources:

Text Books:

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

Reference Books:

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

PROFESSIONAL ELECTIVE – V

MM36006 **3-0-0 (3)**

Machine Learning for Materials Engineers

Pre-Requisites: **None**

Course Outcomes:

CO-1	Distinguish supervised and unsupervised machine learning algorithms
CO-2	Analyze materials datasets with descriptive and predictive methods
CO-3	Compare ML model performance for materials engineering applications
CO-4	Propose new material compositions using ML models

Course Articulation Matrix:

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

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

Syllabus:

Introduction to Machine learning (ML): Basic steps of ML, Supervised and unsupervised learning – Classification, Regression, Clustering, Introduction to online materials databases, Python libraries for materials analysis – pymatgen and mendeleev
Supervised learning: Linear and multi-variate regression, Logistic regression, Cost functions, Regularization, Optimization algorithms, Support Vector Machine (SVM), K Nearest Neighbors (KNN), Training and cross validation, Data pre-processing and feature engineering, Tree-based methods – Decision trees, Bagging, Boosting, Stacked ensemble methods, Neural networks.
Unsupervised learning: Clustering – K-means algorithm and optimization functions.
Introduction to generative models.
ML applications in materials science and engineering - Mechanical property prediction of steels, high entropy alloys (HEAs) and composites, Phase prediction of HEAs, Crystal structure predictions, Tribological property prediction of ceramic materials, Models for process optimization – welding, additive manufacturing, etc., Image data analysis, ML models for materials discovery and design.

Learning Resources:

Textbooks:

1. Kelleher, J. D., Mac Namee, B., & D'arcy, A, Fundamentals of Machine Learning for predictive data analytics: Algorithms, worked examples and case studies, MIT press, 2020.
2. Larose, D. T., Data Mining and predictive analytics, Wiley, 2015, 2nd Edition.
3. Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, Mathematics for Machine Learning, Cambridge University Press, 2020.
4. Yuan Cheng, Tian Wang, Gang Zhang, Editors, Artificial Intelligence for Materials Science, Springer, 2021.
5. Turab Lookman, Francis J. Alexander Krishna Rajan, Editors, Information Science for Materials Discovery and Design, Springer Series in Materials Science, Volume 225, Springer, 2016.
6. Norbert Huber, Surya R. Kalidindi, Benjamin Klusemann, Christian Johannes Cyron, Editors, Machine Learning and Data Mining in Materials Science, Frontiers in Materials, 2020.
7.

Reference Books:

1. Manaranjan Pradhan and Dinesh Kumar, Machine learning using Python, Wiley, 2019.
2. U. Dinesh Kumar, Business Analytics, Wiley, 2017.
3. Olexander Isayev, Alexander Tropsha, Stefano Curtarolo, Editors, Materials Informatics – Methods, Tools and Applications, Wiley-VCH, 2019.

Other Suggested Readings:

1. https://towardsdatascience.com/ - A Medium publication sharing concepts, ideas, and codes.
2. https://machinelearningmastery.com/ by Jason Brownee

MM36008 **3-0-0 (3)**

Light Metals and Alloys

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the relationship between Processing, Microstructure and Properties
CO-2	Design and develop Al - alloys for automotive applications
CO-3	Apply the concepts of microstructure design for high strength Mg- alloy development
CO-4	Apply the concepts of processing for controlling the properties of Ti- alloys

Course Articulation Matrix:

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

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

Syllabus:

General introduction - strengthening by solid solution, precipitation, dispersion, grain refining and work hardening. Production of aluminum, magnesium, and titanium by various methods. Aluminum alloys - Designation, temper and characteristics of cast and wrought aluminum alloys. Magnesium alloys - Alloy designation and tempers, casting alloys, wrought alloys, latest trends in applications of Mg alloys. Titanium alloys - alpha alloys, alpha - beta alloys, beta alloys, fabrication, heat treatments. Metal matrix composites - principles, processing, properties and applications.

Learning Resources:

Text Books:

1. I.J.Polmear, Light Alloys - From Traditional alloys to nanocrystals, Butterworth Heinemann, 2005, 4th Edition
2. T.W. Clyne, P.J. Withers, An introduction to metal-matrix composites, Cambridge University Press, 1993.

Reference Books:

1. R.W.Heine, C.R.Loper, P.C.Rosenthal, Principles of Metal Casting ,Tata McGraw Hill, 1976.
2. D.H. Kirkwood, M. Surey, P. Kapranos, H.V. Atkinson, K.P. Young, Semisolid Processing of Alloys, Springer Series in materials Science, 2010.
3. M. Gupta, N.M.L. Sharon, Magnesium, Magnesium Alloys, and Magnesium Composites, Wiley, 2011

MM36010 **3-0-0 (3)**

Computational Approaches in Materials Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply thermodynamic modelling for alloy design.
CO-2	Apply finite element analysis (FEA) techniques to simulate material behavior.
CO-3	Employ mesoscale modeling methods to solve materials behaviour.
CO-4	Select appropriate simulation approaches based on relevant length and time scales.

Course Articulation Matrix:

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

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

Syllabus:

Basics of computational methods, numerical techniques, and physical modeling of material-related problems. Overview of material structures across different length and time scales and their relevance in modeling. Monte Carlo Methods: fundamentals and applications in material simulations. Molecular modeling: understanding interatomic potentials, prerequisites for molecular dynamics simulations, and the Verlet algorithm. Introduction to Finite Element Analysis (FEA) and Crystal Plasticity: fundamentals, solving one-dimensional (1D) and two-dimensional (2D) problems, and microstructure modeling. Thermodynamic modeling: principles of CALPHAD, use of Thermo-Calc software, alloy design. Integrated Computational Materials Engineering (ICME).

Learning Resources:

Text Books:

1. Richard Laser, Introduction to Computational Materials Science, Cambridge University Press, 2013.
2. Zoe Barber, Introduction to Materials Modelling, Maney Publishing, 2005.
3. June Gunn Lee, Computational Materials Science 2ed., CRC Press, 2016

Reference Books:

1. R J Arsenault, J R Beeler Jr, D M Easterling (Eds): Computer Simulation in Materials Science, ASM International, 1986.
2. B.S. Grewal, Numerical Methods in Engineering and Science, Mercury Learning and Information, 2018

Online Resources:

1. https://nptel.ac.in/courses/115/103/115103114/
2. https://ocw.mit.edu/courses/materials-science-and-engineering/3-320-atomistic-computer-modeling-of-materials-sma-5107-spring-2005/index.htm
3. https://ocw.mit.edu/courses/materials-science-and-engineering/3-021j-introduction-to-modeling-and-simulation-spring-2012/

MM36012 **3-0-0 (3)**

Surface Engineering and coating Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Exploring various principles and techniques for coating deposition.
CO-2	Understanding the parameters involved in different coating processes.
CO-3	Identifying common coating defects and their causes along with methods for prevention and correction.
CO-4	Choosing appropriate coating materials for specific applications considering factors like cost, performance, and environmental impact.
CO-5	Exploring diverse applications of coatings in various industries.

Course Articulation Matrix:

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

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

Syllabus:

Introduction to surface treatments, modifications, and thin film deposition, emphasizing their impact on material properties. Understanding surface reactions, adhesion, and the behavior of materials at interfaces. Electrochemical principles and techniques for coating deposition-different types of electroplating and their applications. Principles and uses of Anodizing, phosphating, dip coating, fluidized bed coating, and powder coating. Thermal spray methods - flame spraying, plasma spraying, and high-velocity oxy-fuel spraying (HVOF) and their applications. Principles and applications of Physical vapor deposition (PVD) and chemical vapor deposition (CVD), sputtering, atomic layer deposition (ALD), and plasma-enhanced CVD.Emerging methods and materials, including nanomaterials and functional coatings. Coating Characterization & Performance-Surface Roughness & Thickness, Adhesion, Friction & Wear, Corrosion Resistance, Mechanical Properties, and Optical Properties. Common coating defects and their causes, along with methods for prevention and correction. Diverse applications of coatings in various industries, such as automotive, aerospace, and electronics.

Learning Resources:

Text Books:

1. Tadeusz Burakowski and Tadeusz Wierzchon, Surface Engineering of Metals: Principles, Equipment, Technologies, CRC Press LLC, 1999
2. K. G. Budinski, Surface Engineering for Wear Resistance, Prentice Hall, New Jersey, 1998.
3. Surface Engineering for Corrosion and Wear resistance, Edited by J. R. Davis, ASM International, 2001
4. Friction and wear of engineering by IM Huctings.

Reference Books:

1. D.S.Rickerby and A.Matthews: “Advanced Surface Coatings: a Handbook of Surface Engineering”, Chapman and Hall, New York, 1991.
2. P.K. Datta and J.S. Burnell-Gray: “Advances in Surface Engineering”; Royal Society of Chemistry, 1997
3. Refer the Journals on Wear, Surface and Coating Technology, Surface Science, Thin Solid Films, Acta Materialia, Vacuum and other related to the lecture syllabus.

MM36014 **3-0-0 (3)**

Advanced Materials Characterization

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explore various characterization techniques for analyzing microstructural and compositional aspects of advanced material.
CO-2	Appraise principles, instrumentation and applications of advanced characterization techniques.
CO-3	Differentiate specimen preparation techniques for various characterization techniques.
CO-4	Choose suitable characterization techniques for a right analysis of advanced materials.

Course Articulation Matrix:

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

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

Syllabus:

Introduction to Materials Characterization-Fundamentals and Overview of Techniques; Microscopy Techniques-Optical Microscopy: Principles, instrumentation, and applications; Scanning Electron Microscopy (SEM): Image formation, sample preparation, and EDS analysis; Transmission Electron Microscopy (TEM): Principles, instrument, and various imaging modes (e.g., HRTEM, STEM); Atomic Force Microscopy (AFM): Basic principles and applications; Spectroscopy Techniques (XPS, XRF, WDS and EDS); Diffraction Techniques-X-ray Diffraction (XRD): Principles, instrumentation, and data analysis; Advanced Diffraction Techniques: (e.g., SAXS); Thermal Analysis Techniques – Principles, instrumentation and applications of TGA, DSC, DTA, TG-DTA, TMA, DMA and dilatometry. Other advanced techniques such as EPMA, EBSD, FEM, FIM, and APM.

Learning Resources:

Text Books:

1. Yang Leng: Materials Characterization-Introduction to Microscopic and Spectroscopic Methods - John Wiley& Sons (Asia) Pte Ltd, 2008
2. ASM Handbook: Materials Characterization, ASM International, 2008.
3. C. Suryanarayana, M. Grant Norton: X-Ray Diffraction-A Practical Approach, Plenum Publishing Corporation, 1998.

Reference Books:

1. Robert F. Speyer: Thermal Analysis of Materials, Marcel Dekker Inc., New York, 1994.
2. V. T. Cherapin and A. K. Mallik: Experimental Techniques in Physical Metallurgy, Asia Publishing House,1967.
3. S.J.B. Reed: Electron Microprobe Analysis, Cambridge University Press, London, 1975.

MM36016 **3-0-0 (3)**

Electronic and Magnetic Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe the principles, applications, and industrial processing of magnetic materials.
CO-2	Design microstructures for enhanced properties of hard and soft magnets.
CO-3	Describe the principles, industrial processing, and structure of semiconducting materials.
CO-4	Discuss the principles, synthesis, and structure of superconducting materials.

Course Articulation Matrix:

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

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

Syllabus:

Magnetic Materials: Principles of magnetism; Classification of magnetic materials; Processing, properties, and structure of hard magnets: hard ferrites, AlNiCo, and rare-earth magnetic materials; and soft magnets: soft ferrites, Fine met, and metallic glasses; Recent advances

Semiconducting Materials: Basic semiconductor principles; Processing of metallurgical and electronic grades of silicon, Growth of single crystals and wafer preparation; Physical vapour deposition (PVD) and chemical vapour deposition (CVD); Lithography; Photovoltaics; Light emitting diodes (LEDs); Recent advances

Superconducting Materials: BCS theory, Type I and II superconductors, Meissner Effect; Processing, properties, and structure of high-temperature superconducting materials: YBCO & Bi-2212; Recent advances

Learning Resources:

Text Books:

1. B. D. Cullity, C.D. Graham, 2nd Ed., Introduction to Magnetic Materials, Wiley and IEEE, 2009
2. J D Patterson, Solid State Physics, 2nd Edition, Springer, 2011.
3. D.M. Hoffman, B. Singh, J.H. Thomas, Handbook of Vacuum Science and Technology, Academic Press 1998.
4. David Jiles, Introduction to Magnetism & Magnetic Materials, London: Chapman & Hall, 1998.
5. Milton Ohring, Materials Science of Thin Films, Academic Press, San Diego, 2002.

Reference Books:

1. John J. Croat, Rapidly Solidified Neodymium-Iron-Boron Permanent Magnets, Woodhead Publishing, 2017
2. G.S. May and C.J. Spanos, Fundamentals of Semiconductor Manufacturing and Process Control, Wiley – IEEE, 2006.
3. Classroom and Lecture Notes

Other Suggested Readings:

1. NPTEL Courses: https://nptel.ac.in/courses/113/106/113106065/

MM36018 **3-0-0 (3)**

BIOMATERIALS

Pre-Requisites: **None**

Course Outcomes:

CO1	Discuss the materials science principles for bio-applications
CO2	Design the processing methods for biomaterials
CO3	Apply different characterization techniques to assess biomaterials properties
CO4	Select materials for different bio-applications

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Overview: Historical development; Materials in Medical Applications; Materials Properties for Bio-applications.

Biomaterials Classification and Processing: Metallic materials; Ceramic and glass implant materials; Polymeric implant materials; Collagen; Thin films; Grafts and coatings; Biological functional materials

Cell Structure: Bone structure; Bone properties; Proteins; Bacteria structure; Antibacterial assay

Cell-material Interaction: In vivo testing; Cell-material interaction; Cell-signaling; in vitro testing; Cytotoxicity; Clinical trials

Tissue Engineering: Scaffolds, cellular materials, stem cells, regeneration engineering

Learning Resources:

Text Books:

1. Buddy D. Ratner: Biomaterial Science- An introduction to Materials in Medicine, Elsevier, 2013.
2. B. Basu, D. Katti and Ashok Kumar; Advanced Biomaterials: Fundamentals, Processing and Applications; John Wiley & Sons, Inc., USA, 2009.
3. B. Basu; Biomaterials Science and Tissue Engineering: Principles and Methods, Cambridge IISc Press, 2017.
4. Lisa A. Pruitt and Ayyana M. Chakravartula: Mechanics of Biomaterials- Fundamental Principles for Implant Design, Cambridge University Press, 2011,

Reference Books:

1. S. V. Bhat, Biomaterials; 2nd Ed., Narosa Publishing House, 2006.
2. J. Park, R.S. Lakes, Biomaterials an introduction; 3rd Ed., Springer, 2007

Online Resources:

https://nptel.ac.in/courses/113/108/113108071

MM36020 **3-0-0 (3)**

HIGH TEMPERATURE MATERIALS

Pre-Requisites: None

Course Outcomes:

CO1	Discuss the oxidation mechanisms of metals and alloys
CO2	Classify materials for high temperature applications
CO3	Explain mechanisms of creep, thermal fatigue, oxidation and hot corrosion
CO4	Select the materials and/or coatings for high temperature applications

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to high temperature Materials, Characteristics of engineering materials at high temperature, oxidation, high temperature corrosion, Creep, thermal fatigue, erosion, aging, structural changes, material damage, crack propagation, damage mechanics, life time analysis.
High temperature materials- Carbon alloy steels, Stainless steels, super alloys and titanium and its alloys, ceramics, composites, Refractory metals, alloys and Structural inter-metallic and high temperature polymers.
Coatings: Thermal barrier coatings, Oxidation resistant coatings.

Textbooks:

1. G. W. Meetham and M. H. Van de Voorde, Materials for High Temperature Engineering Applications (Engineering Materials) Springer; 1 edition, 2000.
2. Neil Birks, Gerald H. Meier, and Frederick S. Pettit, Introduction to the High Temperature Oxidation of Metals by Cambridge University Press; 2 edition, 2009.
3. Sudhansu Bose, High Temperature Coatings, Butterworth-Heinemann; 1 edition, 2007.
4. K. L. Mittal, Polyimides and Other High Temperature Polymers: Synthesis, Characterization and Applications, Brill Academic Publications, 2009.
5. R.W. Evans, and B. Wilshire, Creep of metals and alloys, Institute of Metals, London, 1985.
6. Krishan Kumar Chawla, Composite Materials- Science and Engineering, Springer, 2012.
7. B. Raymond, Seymour and Charles E. CarraherJr, Polymer Chemistry, An Introduction, 2nd Edition, MarcelDekkar, Inc. New York, 1987.
8.

Learning Resources:

Reference Books:

1. J. R. Davis: ASM specialty Hand book: Heat-Resistant materials, ASM,1997.

Online Resources:

1. **https://www.youtube.com/watch?v=7z1KCDq43Zo**

MM36022 **3-0-0 (3)**

Aerospace Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify components of aerospace vehicles and outline material requirements for their design and performance.
CO-2	Recognize conventional and advanced materials utilized in aerospace applications.
CO-3	Compare the applications and performance characteristics of various aerospace materials.
CO-4	Evaluate the suitability of advanced materials for emerging aerospace technologies.

Course Articulation Matrix:

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

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

Syllabus:

Introduction to Aerospace Engineering and Materials: Overview of aerospace vehicles (aeroplanes, space vehicles, missiles); material requirements in aerospace environments.
Identification of Aerospace Components and Material Selection: Components of aerospace structures; material usage in different sections; criticality of material selection for structural integrity, weight reduction, thermal management, and environmental resistance.
Materials for Gas Turbines and Aero Engines: Superalloys (iron, nickel, cobalt base) — composition, microstructure, processing, properties, and applications.
Aluminium Alloys for Aerospace Applications: Cast aluminium alloys — designations, properties, and applications; Wrought aluminium alloys — types, microstructural features, and applications.
Titanium Alloys for Aerospace Applications: Introduction to titanium alloys; Alpha alloys — microstructure, properties, and applications; Alpha-beta alloys — microstructure, properties, and applications; Beta alloys — microstructure, properties, and applications.
Special Steels for Aerospace Applications: Introduction to steels; high-strength steels; stainless steels and maraging steels for aerospace use.
Advanced and Emerging Materials: Intermetallics: Introduction and significance in aerospace applications.
Ceramics: Usage in thermal protection systems and high-temperature applications.
Composites: Fiber-reinforced polymers, metal matrix composites, ceramic matrix composites — properties and applications.

Learning Resources:

Text Books:

1. Balaram Gupta: Aerospace Materials with Material Technology for Engineers, Vol. 1–4, S. Chand & Co., New Delhi, 1996 and 2002.
2. I.J. Polmear: Light Alloys – From Traditional Alloys to Nanocrystals, 4th Ed., Butterworth-Heinemann, 2005.
3. G. Lutjering, J.C. Williams: Titanium, Springer, 2007.
4. George F. Titterton: Aircraft Materials and Processes, Himalayan Books, New Delhi, 1998

5. Michael F. Ashby: Materials Selection in Mechanical Design, Butterworth-Heinemann, 2005
6. F.C. Campbell: Manufacturing Technology for Aerospace Structural Materials, Elsevier, UK, 2006.

Reference Books:

1. Dongliang Zhao, Sam Zhang: Aerospace Materials Handbook, 1st Ed., CRC Press, Taylor & Francis Group, 2013.
2. Joseph R. Davis, Penelope Allen, Steve Lampman, Theodore B. Zorc, Scott D. Henry, Janice L. Daquila, Alice W. Ronke (eds.): Metals Handbook – Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, ASM International, 1990.

MM36024 **3-0-0 (3)**

Welding Metallurgy of Non-Ferrous Metals

Pre-Requisites: None

Course Outcomes:

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

CO1	Discuss the phase transformations in non-ferrous alloys.
CO2	Explain the influence of welding parameters on weldment microstructure and properties.
CO3	Identify welding defects and remedial measures
CO4	Select welding processes for non-ferrous and refractory alloys

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Welding of Aluminium alloys: classification of wrought and cast alloys, designations, non-heat treatable and heat treatable alloys, role of alloying elements, strengthening mechanisms, different welding processes used for aluminium alloys, problems in Al welding, porosity formation in Al welds, hydrogen solubility, Oxide film removal, surface preparation, solidification cracking in Al alloys, grain refinement, filler metal selection, partially melted zone (PMZ), liquation cracking, softening of HAZ, Al welding distortion.

Welding of Titanium alloys: classification of titanium alloys, Applications, Influence of alloying elements, hydrogen solubility in Ti Alloys, Al equivalent, Mo equivalent, Phase transformations, CCT diagrams, different welding processes used for titanium alloys, shielding gases, welding problems, post weld heat treatments, grain boundary alpha problem, issues in post-weld ageing of metastable β alloys, defects in Ti welding, surface colour in Ti welds, hydrogen embrittlement, fillers used in Ti welding

Welding of Magnesium alloys: classification of magnesium alloys, ASTM designation, applications, role of alloying elements, different welding processes used for magnesium alloys, oxide layer problem, shielding gases, surface preparation, loss in HAZ strengthening, stress corrosion cracking, filler metals, welding defects in Mg alloys.

Welding of Ni-base alloys: classification of Ni and Ni alloys, Super alloys, applications, role of alloying elements, strengthening mechanisms, different welding processes used for Ni alloys, shielding gases, filler metals, welding problems, post weld ageing treatments, reversion of

precipitate and loss of strength, strain age cracking, solidification cracking, HAZ liquation cracking

Welding of copper alloys: classification of copper and copper alloys, applications, role of alloying elements, factors affecting weldability, different welding processes used for copper alloys, filler metals, shielding gases, joint designs

Welding of zirconium alloys: grades of Zr, physical metallurgy of Zr, applications, different welding processes used for zirconium alloys, surface preparation, filler metals

Text Books:

1. Gene Mathers, The welding of aluminium and its alloys. Woodhead Publishing Limited, Abington Hall, Abington Cambridge CB1 6AH, England, 2002.
2. I. J. Polmear, Light alloys- from traditional alloys to nanocrystals. Butterworth-Heinemann Linacre House, Jordan Hill, 2006
3. Froes. F, Titanium: physical metallurgy, processing, and applications. ASM international, 2015.
4. Cary, Howard B. and Scott C. Helzer, Modern Welding Technology. Upper Saddle River, New Jersey: Pearson Education, USA, 2005.
5. Sindo Kou, Welding metallurgy, John Willey, 2003, 2nd edition, USA.

Reference Books:

1. Metals Handbook Desk Edition, American Society for Metals, USA, 1998.
2. Welding handbook, American Welding Society, 8th edition, vol.5, USA, 2011.

Online Resources:

1. https://www.twi-global.com/technical-knowledge/faqs/faq-i-have-to-weld-a-non-ferrous-metal-what-does-non-ferrous-mean-and-what-thing
2. https://onlinecourses.nptel.ac.in/noc23_me49/preview.