B.Tech (Four Years)

Course Structure and Syllabi

Department of Metallurgy and Materials engineering

Indian Institute of Engineering Science and Technology (IIEST), Shibpur

Botanic Garden, Howrah

Course Structure for B. Tech. in Metallurgy and Materials Engineering

First Semester

Sl. No.	Type	Course Name	Course code	Class Load/Week			Credit	Class load/ week	Marks
				L	T	P			
1	BSC	Engineering Mathematics – I		3	1	0	4	4	100
2	BSC	Engineering Physics		3	0	0	3	3	100
3	ESC	Introduction to AI and ML		3	0	0	3	3	100
4	ESC	Engineering Mechanics		3	0	0	3	3	100
5	ESC	Engineering Materials	MM1101N	3	0	0	3	3	100
6	VAC	Energy, Environment and Climate Change		2	0	0	2	2	50
		Theory Sub-total		**17**	**1**	**0**	**18**	**18**	**550**
7	ESC	Engineering Graphics		0	0	3	2	3	50
8	BSC	Physics Lab.		0	0	3	2	3	50
9	ESC	Engineering Materials Lab	MM1171N	0	0	3	2	3	50
10		NSS/NCC/PT/Yoga					R*		
		Practical Sub-total		**0**	**0**	**9**	**6**	**9**	**150**
		First Semester Total		**17**	**1**	**9**	**24**	**27**	**700**

Second Semester

Sl. No	Type	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
				L	T	P			
1	BSC	Engineering Mathematics –II		3	1	0	4	4	100
2	BSC	Engineering Chemistry		3	0	0	3	3	100
3	ESC	Basic Electrical Engineering		3	0	0	3	3	100
4	VAC	Well-being and happiness		2	0	0	2	2	50
6	HSC	Professional communication in English		2	1	0	3	3	100
6	PC	Thermodynamics of Materials	MM1201N	3	0	0	3	4	100
		Theory Sub-total		**16**	**2**	**0**	**18**	**19**	**550**
7	ESC	Workshop Practice		0	0	3	2	3	50
8	ESC	Basic Electrical Engineering Lab		0	0	3	2	3	50
9	ESC	Engineering Chemistry Lab		0	0	3	2	3	50
10	PC	Introduction to Materials Lab	MM1271N	0	0	3	2	3	50
		NSS/NCC/PT/Yoga					R*		
		Practical Sub-total		**0**	**0**	**12**	**8**	**12**	**200**
		Second Semester Total		**16**	**2**	**12**	**26**	**31**	**750**

Third Semester

Sl. No	Type	Course Name	Course	Class Load			Credit	Class load/ week	Marks
				L	T	P			
1	ESC	Physics of materials	MM2101N	3	0	0	3	3	100
2	ESC	Strength of Materials		3	0	0	3	3	100
3	PC	Manufacturing Technology	MM2102N	3	0	0	3	3	100
4	PC	Physical Metallurgy	MM2103N	4	0	0	4	4	100
5	PC	Transport Phenomena and Rate Processes	MM2104N	4	0	0	4	4	100
		Theory Sub-total		17	0	0	17	17	500
6	ESC	Physics of materials Lab	MM2171N	0	0	3	2	3	50
7	ESC	Strength of Materials Lab.		0	0	3	2	3	50
8	PC	Physical Metallurgy Lab	MM2172N	0	0	3	2	3	50
9	PC	Transport Phenomena and Rate Processes Lab	MM2173N	0	0	3	2	3	50
		Practical Sub-total		0	0	12	8	12	200
		Third Semester Total		**17**	**0**	**12**	**25**	**29**	**700**

Fourth Semester

Sl. No	Type	Course Name	Course	Class Load/Week			Credit	Class load/ week	Marks
			Code	L	T	P			
1	PC	Deformation Behaviour of Materials	MM2201N	3	1	0	4	4	100
2	PC	Extractive Metallurgy	MM2202N	3	0	0	3	3	100
3	PC	Heat Treatment Technology	MM2203N	3	1	0	4	4	100
4	PC	Materials Characterization	MM2204N	3	1	0	4	4	100
5	OE	OE1		3	0	0	3	3	100
		Theory Sub-total		15	3	0	18	18	500
6	PC	Deformation Behaviour of Materials Lab	MM2271N	0	0	3	2	3	50
7	PC	Extractive Metallurgy Lab	MM2272N	0	0	3	2	3	50
8	PC	Heat Treatment Lab	MM2273N	0	0	3	2	3	50
9	PC	Materials Characterization Lab	MM2274N	0	0	3	2	3	50
		Practical Sub-total		0	0	12	8	12	200
		Fourth Semester Total		**15**	**3**	**12**	**26**	**30**	**700**

Fifth Semester

Sl. No	Type	Course Name	Course Code	Class Load/Week L	T	P	Credit	Class load/ week	Marks
1	PC	Mechanical Testing of Materials	MM3101N	3	0	0	3	3	100
2	PC	Iron and Steel Making	MM3102N	3	0	0	3	3	100
3	PC	Joining of Materials	MM3103N	3	1	0	4	4	100
4	PC	Metal Forming Technology	MM3104N	3	0	0	3	3	100
5	OE	OE2		3	0	0	3	3	100
		Theory Sub-total		15	1	0	16	16	500
6	PC	Mechanical Testing of Materials Lab	MM3171N	0	0	3	2	3	50
7	PC	Joining of Materials Lab	MM3172N	0	0	3	2	3	50
8	PSE	PSE1: Solidification Processing Lab	MM3173N	0	0	3	2	3	50
9	PSE	PSE2: Metal Forming Lab	MM3174N	0	0	3	2	3	50
		Practical Sub-total		0	0	12	8	12	200
		Fifth Semester Total		**15**	**1**	**12**	**24**	**28**	**700**

Sixth Semester

Sl. No	Type	Course Name	Course Code	Class Load/Week L	T	P	Credit	Class load/ week	Marks
1	PC	Degradation of Materials	MM3201N	3	0	0	3	3	100
2	PSE	PSE3 (Alloy Steel & Cast Iron/Ceramic and Composite Materials)	MM3221N/ MM3222N	3	0	0	3	3	100
3	PSE	PSE5 (Computational Materials Engineering/ Electronic and Magnetic Materials)	MM3223N/ MM3224N	3	0	0	3	3	100
4	HSC	Finance Economics and Management for Engineers		3	0	0	3	3	100
5	OE	OE3		3	0	0	3	3	100
		Theory Sub-total		17	0	0	15	17	500
6	PC	Degradation of Materials Lab	MM3271N	0	0	3	2	3	50
7	PSE	Alloy Steel & Cast Iron lab/Ceramic and Composite Lab	MM3272N/ MM3273N	0	0	3	2	3	50
8	PSE	PSE 6: Materials Design Project I	MM3291N	0	0	3	2	3	50
		Practical Sub-total		0	0	9	6	9	150
		Sixth Semester Total		**17**	**0**	**9**	**21**	**26**	**650**

Seventh Semester

Sl. No	Type	Course Name	Course Code	Class Load/Week			Credit	Class load/ week	Marks
				L	T	P			
1	PSE	PSE4 (Stainless Steel Technology / Powder Metallurgy)	MM4121N/ MM4122N	3	0	0	3	3	100
2	PSE	PSE 6 (Fracture and Failure Analysis / Non Destructive Testing)	MM4123N/ MM4124N	3	0	0	3	3	100
3	VAC	Sociology & Professional Ethics		3	0	0	3	3	100
4	OE	OE4	#	3	0	0	3	3	100
		Theory Sub-total		12	0	0	12	12	400
5	PC	Machine Learning in Materials Lab	MM4171N	0	0	3	2	3	50
6	PC	Stainless steel technology Lab/ Powder Processing Lab	MM4172N/ MM4173N	0	0	3	2	3	50
7	I	Internship	MM4191N						
		Practical Sub-total		0	0	0	0	0	100
		Seventh Semester Total		**12**	**0**	**0**	**12**	**12**	**500**

Eighth Semester

Sl. No	Type	Course Name	Course Code	Class Load/Week			Credit	Class load / week	Marks
				L	T	P			
1	OE	OE5 (from NPTEL for the students opting Internship/ for others from Institute)	#	3	0	0	3	3	100
		Theory Sub-total		3	0	0	3	3	100
2	I/P	One Semester Internship / Project	MM4291N				8		300
3	O	Grand viva	MM4292N				2		50
		Practical Sub-total		0	0	0	10	0	350
		Eighth Semester Total		**3**	**0**	**0**	**13**	**3**	**450**

# Open Elective Subject from 4th to 8th Semester		
OE1	Selection of Engineering Materials	MM2261N
OE2	Materials for Structural Applications	MM3161N
OE3	Materials for Aerospace Applications/	MM3261N
OE3	Functional Materials	MM3262N
OE4	Machine Learning in Materials	MM4161N
OE5	Biomaterials	MM4261N

Syllabus: First Semester

Course Code	MM1101N	Course Name	Engineering Materials	Course Category	ESC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	To introduce foundational concepts of materials science and engineering, with a focus on the applications of materials in various industries.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	*Introduction*: Classification of materials, Physical properties of materials, Testing of materials: mechanical and electrical properties	6	Students will gain an overview of different classes of materials and relevant physical properties.
II	*Ceramics, Polymers, and Composites* *Ceramic materials:* Structure and general properties of glasses and ceramics, Forming and Shaping of Ceramics and Glasses, Techniques for Strengthening and Annealing Glass *Polymer materials:* Structure, General Properties and Applications, Processing of polymers *Composite materials:* Classification, Areas of application of composite materials, Methods of manufacturing composites	6	Students will be introduced to structure and manufacturing methods of ceramics, polymers, and composites.
III	Processing of metals and alloys *Metal casting technologies:* A brief introduction to the casting of metals and alloys, classification of casting processes, basics of sand casting *Metal Forming and Shaping Processes:* Rolling, Open die forging, Forgeability of metals	6	Students will learn about different industrial processes of generating metallic structures/components.
IV	*Surface Treatment and degradation of materials*: Mechanical plating and cladding, Case hardening, Thermal Spraying, Vapour deposition, Electroplating, Types of corrosion, Methods to control corrosion: coatings, inhibitors, cathodic protection, Corrosion testing: Immersion test and salt-spray test	6	Students will learn about different techniques employed to protect engineering materials from environmental degradation.
V	*Materials for Structural Applications:* Introduction, Categories of structural materials, Strategies of selection of materials and processes for structural applications	5	Students will learn about different materials used for making buildings, turbines, armours and other civil/mechanical structures.

VI	*Materials for transportation:* Categories of materials used in the automobile, railway and aerospace industries, Strategies of selection of materials and processes for applications in the transportation industry	5	Students will get introduced to different materials used in cars, trains, ships, airplanes and spacecrafts, and how to select these materials.
VII	*Electronic Materials:* Overview and definitions, Categories of electronic materials used in the semiconductor industry, Manufacturing processes of electronic materials: Crystal growing and wafer preparation, Film deposition, Oxidation, Lithography, Etching	4	Students will learn about different materials used in making chips, sensors and actuators and associated manufacturing processes.
VIII	*Materials for Biomedical Applications*: Metallic, ceramic and polymeric biomaterials, Materials for tissue engineering	4	Students will learn about different materials used for surgical implants and in biomedical industries.

Course Outcome	CO1: On completion of this course, the students should be able to classify materials and processes and identify/compare physical properties of materials CO2: The students should get a basic understanding of the processes associated with the processing of metallic, ceramic and polymeric components of a device/structure CO3: The students should know about different methods of joining materials and how to protect materials from degradation. CO4: The students should become familiar with materials and manufacturing processes associated with the construction, energy, transportation, semiconductor and biomedical industries.

Learning Resources	Text Book(s): Manufacturing Engineering and technology, S. Kalpakjian, S. R. Schmid, K. S. Vijay Sekar, Pearson Materials Science and Engineering, William D. Callister, Jr. Wiley India (P) Ltd. Reference Book(s): Materials Science and Engineering: A First Course, V. Raghavan, Prentice Hall India Learning Private Limited

Course Code	MM1171N	Course Name	Engineering Materials Lab	Course Category	ESC	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	
	● To introduce students to a wide range of engineering materials and their key characteristics. ● To provide hands-on experience with key engineering materials and their processing methods. ● To develop skills in microstructural preparation, mechanical and electrical testing. ● To understand the relationship between material structure, properties, and performance.

Module	Syllabus	Duration (class-hour)	Module Outcome
1	Introduction & Materials Gallery Visit: Safety briefing and guided tour of a materials gallery with samples from all major material classes and applications.	03	Understand laboratory safety; identify and classify different material classes and their typical applications.
2	Metal Casting Process: Hands-on session on sand casting – mold making, pouring, and solidification.	03	Perform sand casting; understand the process of mold design, metal pouring, and solidification behavior.
3	Polymer Processing – 3D Printing: FDM 3D printing of thermoplastics; design considerations and demo print.	06	Understand FDM 3D printing; recognize thermoplastic behavior; apply design principles in additive manufacturing.
4	Powder Metallurgy: Compaction & Sintering: Demonstration and practice of powder pressing and sintering techniques.	03	Comprehend powder metallurgy processes; conduct powder compaction and understand sintering mechanisms.
5	Sample Preparation for Microstructural Analysis – I: Cutting, mounting, and grinding of metallic samples.	03	Carry out sample preparation steps for metallography; develop precision in mechanical preparation.
6	Sample Preparation for Microstructural Analysis – II: Polishing, etching, and microstructure observation using optical microscopy.	03	Polish and etch samples; operate an optical microscope; identify microstructural features.

7	Materials Joining – Welding & Adhesives: Basic welding (demo or hands-on) and adhesive bonding for different materials.	03	Understand principles of welding and adhesives; compare joining methods and evaluate joint quality.
8	Mechanical Testing – Tensile: Tensile test to determine strength and ductility.	03	Conduct tensile tests; interpret stress-strain curves; evaluate mechanical properties like strength and ductility.
9	Hardness Testing: Performing Vickers hardness tests.	03	Understand and perform Vickers hardness test; correlate hardness values with material structure and properties.
10	Resistivity Measurement – Demonstration: Demonstration of electrical resistivity testing of various materials.	03	Learn techniques to measure electrical resistivity; interpret results in the context of material type and structure.
11	Materials Degradation – Corrosion Testing: Observation of corrosion in metals via immersion test; effects of environment and pH.	03	Observe corrosion behavior in different environments; understand the influence of pH and corrosive media.
12	Project	09	Integrate knowledge from all modules; design and conduct a simple experiment or study related to material processing, testing, or application.

Course Outcome	By the end of this course, students will be able to identify different engineering materials, understand their processing methods, perform basic characterization and testing, and relate material structure to its properties and performance.

Learning Resources	Laboratory Handbook

Syllabus: Second Semester

Course Code	MM1201N	Course Name	Thermodynamics of Materials	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	
	■ To provide the fundamental knowledge in the area of thermodynamics of materials science and metallurgical processes. ■ To aid the development of skills involving the application of fundamental concepts to the practical material problems and metallurgical processes.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction:** Basics of thermodynamics, description of thermodynamic systems and processes, state function/variables, equation of state and thermodynamic properties.	5	Understand energy principles, heat-work conversion, and system behavior, forming the foundation for mechanical, chemical, and physical processes.
II	**Laws of Thermodynamics:** Zeroth law of thermodynamics, first law of thermodynamics, concept of internal energy, heat engines, second law of thermodynamics, concept of entropy, entropy maximization, thermodynamic potentials, equilibrium, concept of natural variables, auxiliary thermodynamic variables and third law of thermodynamics.	6	To comprehend energy conservation, entropy, and equilibrium governing physical, chemical, and engineering thermodynamic processes.
III	**Specific Heat Capacity:** Basics, calculation of thermodynamic properties its application for studying phase transformation.	6	The Students will be able to understand the heat energy required to change the substance temperature, aiding thermal system design and analysis.
IV	**Phase coexistence in unary systems**: Clausius-Clapeyron equation and Gibbs Phase rule.	5	To understand the equilibrium between phases in single-component systems for analyzing phase transitions and material behavior.
V	**Thermodynamics of Solutions:** Partial molar quantities, ideal solutions, dilute solutions and regular solutions. The regular solution model (Quasi-chemical theory) and stability of solutions.	5	The Students will be able to understand the energy changes and equilibrium in mixtures, essential for solution behavior and process design.
VI	**Free energy composition diagrams and its applications:** Construction of binary phase diagrams and basics of ternary phase diagrams.	6	To understand thermodynamic properties, energy interactions, and equilibrium behavior of

			alloys for predicting phases and construct the phase-diagrams.
VII	**Introduction to the statistical thermodynamics:** Concept of microstates and macrostates, the Ergodic hypothesis, thermodynamic ensembles, partition functions, thermodynamic property calculations, Boltzmann hypothesis and distribution.	4	To link microscopic particle behavior with macroscopic thermodynamic properties using probability and statistical methods for deeper insight.
VIII	**Reacting Multiphase Systems:** Gas-condensed phase reactions, Ellingham diagrams and their applications for metallurgical processes.	5	To analyze energy exchanges, phase equilibria, and stability in systems with multiple phases under reacting conditions.

Course Outcome	1. Students will have a thorough understanding of the fundamental concepts of materials thermodynamics. 2. Students will be able to analyse thermodynamic systems and solve industrial problems involving thermodynamic variables. 3. Students will have an understanding of the various assumptions and limitations of various thermodynamic models.

Learning Resources	1. Textbook of Materials and Metallurgical Thermodynamics, Ahindra Ghosh, PHI Eastern Economy edition. 2. Introduction to the Thermodynamics of Materials, David R. Gaskell, Taylor and Francis. 3. Statistical mechanics: A survival guide, A. M. Glazer and J. S. Wark, Oxford University Press.

Course Code	MM1271N	Course Name	Introduction to Materials Lab	Course Category	PC	L	T	P

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	
	• The primary objective is to make the students understand and apply different testing techniques used to characterize engineering materials. • Evaluation of properties of different engineering materials through hands-on experience. • The students should be able to interpret the test results and perform structure-property correlations.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Sample Preparation for Microstructural Analysis – Cutting, mounting, and grinding of metallic samples.	06	Hands-on experience on sample handling and the process to prepare the sample for microstructure
II	Metallography – practicing sample preparation, polishing, and etching	06	To understand the process of revealing the microstructure by polishing and etching.
III	Introduction to Electrical Discharge Machine (EDM) technique for material removal and preparation of complex shapes.	03	To understand the principles, process parameters, and applications of EDM for precision material removal.
IV	Revealing microstructure with optical microscopy – demonstration with some ferrous and non-ferrous samples. Measurement of grain size and microstructure identification	03	To understand the utility of optical microscopy for different samples.
V	Scanning Electron Microscopy (SEM) – Introduction and demonstration. Identification of microstructure with some ferrous and non-ferrous samples.	03	To understand the surface morphology, composition, and microstructure of materials using high-resolution electron imaging techniques.
VI	X-Ray Diffraction – Introduction and demonstration, phase identification.	03	To determine crystal structure, lattice parameters, and phase identification through the interaction of X-rays with matter.
VII	Introduction to materials fabrication – demonstration of rolling and forging processes	03	To understand processes and techniques for shaping, forming, and assembling materials into components and engineered products.

VIII	Introduction to mechanical testing – demonstration of tensile test, hardness impact test and Erichsen cupping test	06	To evaluate material properties like strength, hardness, and ductility to ensure performance and safety in engineering applications.
IX	Introduction to thermal analysis techniques - Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis (TGA)	06	To gain practical skills in thermal analysis techniques for studying material properties, phase changes, and reaction behaviors.

Course Outcome	➢ By the end of this course, students will be able to prepare samples for microstructural observation, identify various ferrous and non-ferrous materials. ➢ Identify various phases present in the sample and perform basic mechanical tests. They should also be able to correlate the microstructure. With mechanical properties.

Learning Resources	Laboratory Handbook

Syllabus: Third Semester

Course Code	MM2101N	**Course Name**	Physics of Materials	**Course Category**	ESC	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	**Co-requisite Courses**	*NIL*	**Progressive Courses**	
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	

Course Objective	
	• To provide students with a fundamental understanding of the physical principles that govern the behavior of materials, starting from classical models and progressing to quantum and solid-state theories. • To develop the ability to analyze and interpret electronic, thermal, optical, magnetic, and superconducting properties of materials, and to relate these properties to their atomic and electronic structure for applications in materials engineering.

Module	**Syllabus**	**Duration (class-hour)**	**Module Outcome**
1	**Classical Electron Theories**: Drude's theory of electrical and thermal conductivity, limitations of classical models. Introduction to free electron theory, energy distribution of electrons.	5	Understand classical theories of electrical and thermal conduction; identify limitations and motivate the need for quantum models.
2	**Foundations of Quantum Mechanics**: Wave-particle duality, de Broglie relations, uncertainty principle. Schrödinger equation, wave functions, and probability interpretation. Solutions to particle in a box, potential wells, and tunneling. Qualitative treatment of harmonic oscillator and hydrogen atom.	6	Develop foundational understanding of quantum mechanics; solve basic quantum problems and interpret physical meaning of wave functions.
3	**Quantum Free Electron Model and Band Theory**: Sommerfeld model, Fermi-Dirac statistics, occupation probability. Periodic potentials, Bloch's theorem, Brillouin zones, and energy bands. Band structure of metals, semiconductors, and insulators.	6	Apply quantum statistics and electron behavior in solids; explain band formation and classify materials based on electronic structure.
4	**Thermal Properties of Materials**: Classical view: Dulong–Petit law, limitations. Quantum models: Einstein and Debye theories of specific heat. Thermal conductivity in metals and insulators, phonons, and lattice vibrations.	5	Analyze specific heat capacity using classical and quantum models; understand phonons and thermal transport in solids.

5	**Semiconductors and Ionic Conduction**: Intrinsic and extrinsic semiconductors, carrier statistics, temperature dependence. Ionic conduction mechanisms: defect equilibria, diffusion, conduction in glasses, role of stoichiometry and dopants.	6	Explain semiconductor behavior using carrier statistics; analyze ionic conduction mechanisms and the role of defects and dopants.
6	**Optical Properties**: Interaction of light with materials: absorption, reflection, refraction, and transmission. Electronic transitions, optical band gap, transparency, and opacity.	7	Understand light-matter interaction; explain optical behaviors and band gap concepts in different materials.
7	**Magnetic Properties and Superconductivity**: Atomic origin of magnetism: orbital and spin moments. Diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, and ferrimagnetism. Magnetic hysteresis, soft and hard magnets. Basics of superconductivity, Meissner effect, critical parameters, Type I and II behavior.	7	Describe magnetic behavior based on electronic structure; distinguish magnetic types; understand key concepts in superconductivity.

Course Outcome	• By the end of the course, students will be able to understand and apply classical and quantum models to explain the electronic, thermal, optical, magnetic, and superconducting properties of materials. • They will gain insight into band structures, charge carrier behavior, and conduction mechanisms in metals, semiconductors, and ionic solids, enabling them to relate fundamental physical principles to material structure and performance.

Learning Resources	Physics of Materials: Essential Concepts of Solid-State Physics, Prathap Haridoss, Wiley (2015) Physics of Materials, 1st Edition, Y. Quere CRC Press (1998) Solid State Physics, 2nd edition, J.S. Blakemore, Cambridge University Press (1985)

Course Code	MM2102N	Course Name	Manufacturing Technology	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	The primary objective of this course is to familiarize the students with different techniques of processing and shaping materials across a wide range of industries

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction and Overview of Manufacturing: Materials in manufacturing, Manufacturing processes, Production systems, Trends in Manufacturing	3	Students will get an overview of different manufacturing processes
II	Glass-working, Shaping processes for plastics, Rubber processing, Polymer matrix composites	6	Students will learn about processing methods employed for shaping glasses, rubbers and composites.
III	Powder Metallurgy and Mechanical Alloying: Powder production, Conventional pressing and sintering, Alternative pressing and sintering, Materials and products for powder metallurgy, Mechanical Alloying	12	Students will learn about the processes involved in powder metallurgy based manufacturing
IV	Machining, Cutting-tool technology, Economy and Product design consideration in machining, Grinding and other abrasive processes, Nontraditional machining and thermal cutting processes	5	Students will become familiar with different subtractive processes.
V	Processing of Integrated Circuits: Silicon processing, Lithography, Layer Processes used in IC fabrication, Integrating the fabrication steps, IC packaging, Yields in IC processing Micro and Nanofabrication	6	Students will become familiar with microfabrication processes employed for making IC chips
VI	Non-equilibrium processing of Materials: Rapid solidification, Laser forming, Bulk amorphous alloy production	4	Students will learn about different manufacturing processes of bulk metallic glasses
VII	Advanced manufacturing techniques: Rapid prototyping, Bio-manufacturing (Computer Aided Tissue Engineering Scaffold Fabrication, CAD Assembly Process for Bone Replacement Scaffolds in Computer-Aided Tissue Engineering)	8	Students will become familiar with manufacturing processes of biomedical components

Course Outcome	CO1: On completion of the course, students should become familiar with different manufacturing processes CO2: Students should be able to choose appropriate manufacturing processes for different types of materials

Learning Resources	1. Fundamentals of Modern Manufacturing by Mikell P. Groover 2. Non-equilibrium Processing of Materials by C. Suryanarayana 3. Virtual Prototyping and Bio Manufacturing in Medical Applications by Bopaya Bidanda and Paulo Bartolo

Course Code	**MM2103N**	Course Name	**Physical Metallurgy**	Course Category	**PC**	L	T	P
						3	**0**	**0**

Pre-requisite Courses	*NIL*	Co-requisite Courses	*NIL*	Progressive Courses	*NIL*
Course Offering Department		**Metallurgy and Materials Engineering**		Data Book / Codes/Standards	*NIL*

Course Objective	To develop a fundamental understanding of the structure, phase diagram, phase transformations, and properties of metallic materials, enabling students to analyze and tailor microstructures by heat treatment and alloy design for desired engineering performances.

Module	Syllabus	Duration (hour)	Module Outcome
Module - I	**Introduction to Physical Metallurgy** Course overview and the importance of understanding material structure-property relationships.	**3**	Understand the course scope and appreciate the critical role of structure-property relationships of engineering materials.
Module -II	**Crystal Structure and Defects** Atomic structure and metallic bonding, Crystal systems and unit cells, details of BCC, FCC, and HCP; Crystallographic planes and directions; Types of crystal defects: point defects, dislocations, and grain boundaries; Effect of defects on material properties	**4**	Recognize crystal structures, defects, and their influence on properties and performances of engineering materials.
Module - III	**Diffusion in Solids** Introduction to diffusion and its importance in metallurgy; Fick's First and Second Laws; Solution methods for Fick's laws- applications in carburizing and nitriding; Diffusion in substitutional and interstitial systems; Diffusion mechanisms; Factors affecting diffusion.	**4**	Understand the principles, laws, mechanisms, and influencing factors of diffusion in solids, with applications in metallurgical processes both substitutional and interstitial atoms.
Module - IV	**Solidification and Microstructural Development** Thermodynamics and kinetics of solidification; Nucleation and growth; Homogeneous vs heterogeneous nucleation; Grain formation and dendritic growth; Segregation; Casting defects and structure control.	**6**	Analyze solidification thermodynamics and kinetics, nucleation types, grain and dendritic growth, segregation, and casting defects to understand and control microstructural development in solidified materials.
Module - V	**Phase Diagrams and Equilibrium Structures** Gibbs phase rule and phase equilibrium; Binary phase diagrams: isomorphous, eutectic, peritectic, and eutectoid systems; $Fe\text{-}Fe_3C$ phase diagram; Lever rule and phase fraction calculations; Construction and interpretation of phase diagrams; Applications in alloy design and processing	**8**	Interpret phase diagrams using Gibbs phase rule, lever rule, and phase equilibria to analyze binary systems and $Fe\text{-}Fe_3C$ diagram for alloy design, processing, and equilibrium microstructure prediction.
Module - VI	**Phase Transformations and Heat Treatments**	**8**	Understand thermodynamics and kinetics of phase transformations, nucleation and growth, TTT/CCT

	Thermodynamics and kinetics of phase transformations; Nucleation and growth mechanisms; Diffusional and diffusionless transformations; Time-Temperature-Transformation (TTT) and Continuous-Cooling-Transformation (CCT) diagrams; Equilibrium and non-equilibrium transformation of austenite in steels; Precipitation hardening in non-ferrous alloys (e.g., Al-Cu)		diagrams, diffusional and diffusionless changes, equilibrium and non-equilibrium transformations of austenite in steels, and precipitation hardening in non-ferrous alloys.
Module - VII	**Strengthening Mechanisms in Metallic Materials** Grain size refinement and the Hall-Petch relationship; Solid solution strengthening; Strain hardening; Precipitation and dispersion strengthening; Composite strengthening mechanisms and trade-offs.	**6**	Develop a deep understanding of various strengthening mechanisms and their trade-offs to effectively design and engineer advanced metallic materials with tailored mechanical properties.
Module - VIII	**Structure-Property Correlations** Significance of structure-properties-processing relationship of engineering materials	**3**	Understand the interrelationship between processing, structure, and properties of engineering materials to predict and tailor material behavior for specific applications.
	Total	**42**	

Course Outcome	On completion of the course, the students should be able to **CO1:** Explain the fundamental concepts of crystal structures, defects, and phase diagrams relevant to metallic materials. **CO2:** Analyse phase transformations and microstructural evolution during various heat treatment processes. **CO3**: Apply metallurgical principles to evaluate and control the mechanical properties of metals through microstructural engineering.

Learning Resources	1. **Phase Transformations in Metals and Alloys**, D.A. Porter, K.E. Easterling & M.Y. Sherif 2. **Materials Science and Engineering: An Introduction,** W.D. Callister Jr 3. **The Science and Engineering of Materials**, D.R. Askeland &W.J. Wright 4. **Physical Metallurgy Principles,** R. Abbaschian & R.E. Reed-Hill 5. **Physical Metallurgy and Advanced Materials,** R.E. Smallman & A.H.W. Ngan

Course Code	MM2104N	Course Name	Transport Phenomena and Rate Processes	Course Category	PC	L	T	P
						4	0	0

Pre-requisite Courses	Engineering Mathematics – I, II	Co-requisite Courses	Nil	Progressive Courses	Extractive Metallurgy, Iron and Steel Making
Course Offering Department		Metallurgy and Materials Engineering		**Data Book / Codes/Standards**	Nil

Course Objectives	The primary objective of this course is to equip students with appropriate concepts and tools that they can apply in solving metallurgical/materials industry-oriented problems involving heat, mass and momentum transfer

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction**: Introduction to momentum, energy and mass transport: mathematical similarity in constitutive equations, Introduction to chemical kinetics, Applications in metallurgical/materials industries	2	Students will get introduced to the differential equation(s) common to momentum, energy and mass transfer
II	**Momentum Transport**: Newton's law of viscosity, Shell momentum balance, Reynolds Transport Theorem, Scaling laws, Concepts of Laminar and Turbulent flow, Concept of boundary layer, Friction factor, Dimensionless numbers	10	Students will understand mathematical equations and boundary conditions associated with fluid flow.
III	**Energy Transport**: Fourier's law of heat conduction, Theories of thermal conductivity, Shell Energy Balances and Temperature distribution in Solids, Heat transfer coefficients for forced convection, Black body radiation	8	Students will understand mathematical equations and boundary conditions associated with heat conduction, convection and radiation
IV	**Mass Transport**: Steady and unsteady diffusion, Fick's laws of diffusion, Applications of diffusion equations in metallurgy	10	Students will understand laws for steady, unsteady and pseudo-steady state diffusion
V	**Homogeneous and heterogeneous reactions:** Introductory concepts of kinetics of heterogeneous reactions, Law of mass action, Integrated Rate Equations, Arrhenius equation	2	Students will be able to differentiate between homogeneous and heterogeneous equations, and derive activation energy
VI	**Kinetics of Reactions of Porous Solids with Gases**: Diffusion of gases through porous solids, Kinetics of reduction of oxides by gases, Kinetics of gasification of carbon by carbon dioxide, Kinetics of reduction of iron oxide by carbon	4	Students will be able to understand mathematical models governing oxidation of metals and reduction of metal oxides.
VII	**Electrochemical Kinetics:**	3	Students will be able to understand the basic equations governing electrolytic deposition and corrosion.

Course Outcome	CO1: On completion of this course, the student should be able to apply the principles of momentum, heat, and mass transfer to solve problems in processing of materials CO2: The student should be able to appreciate the importance of reliable input, in the form of properties, initial and boundary conditions, to material processing software. CO3: The student should get a basic understanding of kinetic processes. CO4: The student should be able to understand mathematical models for oxidation of metals, reduction of metal oxides and electrochemical kinetics.

Learning Resources	Text Book(s): Transport Phenomena, R. B. Bird, W. E. Stewart, E. N. Lightfoot, Wiley A Textbook of Metallurgical Kinetics, A. Ghosh and S. Ghosh, PHI Learning Pvt. Ltd. Reference Book(s): Transport Phenomena in Materials Processing, D. R. Poirier, G. H. Geiger, Springer

Course Code	MM2171N	Course Name	Physics of Materials Laboratory	Course Category	ESC	L	T	P
						0	0	3

Pre-requisite Courses	*NIL*	Co-requisite Courses	*NIL*	Progressive Courses	
Course Offering Department		*Metallurgy and Materials Engineering*		Data Book / Codes/Standards	

Course Objective	• To develop hands-on skills in characterizing materials using experimental techniques and software tools • To interpret data critically and connect laboratory observations with physical principles covered in the theory course.

Module	Syllabus	Duration (class-hour)	Module Outcome
1	**Atomic Packing and Visualization using VESTA**: Introduction to crystal structures and visualization of atomic packing in different unit cells using VESTA software.	3	Understand different crystal systems and unit cells; visualize atomic arrangements and calculate packing efficiencies using VESTA.
2	**X-ray Diffraction: Crystal Structure Determination**: Study of XRD patterns, Bragg's Law, and phase identification of crystalline materials.	3	Interpret XRD patterns using Bragg's law; identify phases and analyze crystal structure of materials.
3	**Concept of Diffraction and Reciprocal Lattice**: Hands-on exercises and simulations to understand reciprocal space and diffraction conditions.	3	Understand diffraction conditions and construct reciprocal lattices; relate them to real-space crystal geometry.
4	**Stereographic Projection and Crystal Orientation**: Construction and interpretation of stereographic projections for different crystal systems.	3	Learn stereographic projection methods; analyze and interpret crystallographic directions and planes.
5	**Electron-Matter Interaction**: Introduction to Scanning Electron Microscope, imaging modes, and analysis of electron-matter interaction outcomes.	3	Understand SEM operation and contrast mechanisms; interpret SEM images and link them to surface features.
6	**Resistivity and Conductivity Measurements (Four-point Probe)**: Measurement of resistivity of metals and semiconductors using the four-point probe method.	3	Measure electrical resistivity and conductivity; compare electrical properties of metals and semiconductors.

7	**Electrical Mobility Measurement via I-V Characteristics of a Transistor**: Extraction of mobility from field-effect transistor characteristics.	3	Analyze I-V characteristics of FETs; extract and understand charge carrier mobility in semiconductors.
8	**Measurement of Dielectric Constant and Relaxation Time**: Capacitance measurements as a function of frequency and analysis using equivalent circuit models.	3	Measure dielectric properties; model frequency-dependent behavior and calculate relaxation time.
9	**Nyquist Plot Analysis and Dielectric Behavior**: Impedance spectroscopy, plotting and interpreting Nyquist plots for dielectric materials.	3	Perform impedance measurements; interpret Nyquist plots and extract dielectric parameters.
10	**Integrated Case Study – Physical Analysis of a Material System**: Guided investigation of practical material problems, identifying relevant physical properties.	9	Integrate concepts to evaluate a material system; relate physical measurements to real-world material performance.
11	**Problem Solving and Project Discussion**: Application of lab learning to solve materials-related case problems; students present experimental observations and analysis.	6	Develop analytical and presentation skills; apply lab concepts to solve complex material problems and interpret data critically.

Course Outcome	• Students will acquire practical skills in characterizing and analyzing the physical properties of materials using experimental tools and software. • They will be able to connect observations with theoretical models and apply them to real-world materials challenges.

Learning Resources	Laboratory Handouts

Course Code	**MM2172N**	Course Name	**Physical Metallurgy Laboratory**	Course Category	**PC**	L	T	P
						0	**0**	**3**

Pre-requisite Courses	*NIL*	Co-requisite Courses	*NIL*	Progressive Courses	*NIL*
Course Offering Department		**Metallurgy and Materials Engineering**		Data Book / Codes/Standards	*NIL*

Course Objective	To provide students with hands-on experience in the characterization, analysis, and processing of metals and alloys, enhancing their understanding of the relationship between microstructure, properties, and performance of materials through experimental techniques and data interpretation.

Lab.	**Syllabus/Plan**	**Duration (h)**	**Lab. Outcome**
Lab. 1	**Metallographic Sample Preparation-I:** Sectioning, Cold and Hot Mounting	**3**	Understand and perform proper sectioning and mounting techniques (cold and hot) to prepare metallographic samples without altering microstructure.
Lab. 2	**Metallographic Sample Preparation-II:** Grinding, Polishing **and Etching**	**3**	Acquire skills in grinding, polishing, and etching to reveal the microstructure of metallic samples.
Lab. 3	**Metallographic Sample Preparation-III:** Etching of Ferrous and Non-ferrous Samples	**3**	Understand and apply appropriate etching techniques to reveal the microstructural features of ferrous and non-ferrous samples for accurate metallographic interpretation.
Lab. 4	**Optical Microscopy:** Operation, Examination and Image Capturing	**3**	Operate an optical microscope, examine metallographic samples, and capture quality images for microstructural analysis.
Lab. 5	**Examinations of as-cast macro and micro-structures**	**3**	Identify and analyze macro and microstructures of as-cast metals/alloys to understand solidification features and defects.
Lab. 6	**Understanding the Cu-Zn phase diagram by microstructural characterization**	**3**	Correlate Cu-Zn phase diagram with microstructural features of single and two-phase brass alloys through metallographic analysis.
Lab. 7	**Microstructural examinations of various non-ferrous alloys**	**3**	Analyze the microstructures of different non-ferrous alloys to understand their processing history and phase constituents.
Lab. 8	**Understanding the eutectoid transformation via microstructural evaluation of plain-carbon annealed steels with different carbon contents**	**3**	Examine how carbon content affects microstructure in annealed plain-carbon steels undergoing eutectoid transformation.
Lab. 9	**Understanding the CCT diagram by microstructural evaluation of eutectoid steel subjected to different cooling rates**	**3**	Interpret continuous cooling transformation behavior in eutectoid steels by analyzing microstructures formed at various cooling rates.

Lab. 10	**Understanding the microstructural variation of cast irons**	**3**	Differentiate types of cast iron and understand how composition and processing influence their microstructural characteristics.
Lab. 11	**Understanding the microstructures of various advanced high-strength steels**	**3**	Analyze and compare microstructures of various advanced high-strength steels to understand their phase compositions and strengthening mechanisms.
Lab. 12	**Evaluation of the recrystallization process via microstructure examination and hardness measurement**	**3**	Study the effects of cold work and subsequent annealing on microstructure and hardness to understand the recrystallization process.
Lab. 13	**Measurement of grain size and quantification of phases by image analysis**	**3**	Perform grain size measurement and quantify microstructural phases using image analysis software for metallurgical evaluation.
Lab. 14	**Test and viva**	**3**	Assess theoretical and practical understanding of metallography, phase transformations, and microstructural analysis through comprehensive testing and oral examination.

Course Outcome	On completion of the course, the students should be able to **CO1:** ***Develop practical skills in metallographic sample preparation and microstructural analysis*** *of ferrous and non-ferrous metals using optical microscopy.* **CO2:** ***Analyze and interpret experimental data related to phase diagrams, phase transformations,*** *and their effects on mechanical properties using modern laboratory tools and techniques.* **CO3**: ***Demonstrate critical thinking,*** *collaborative laboratory work,* ***and*** *effectively communicate findings through technical reports.*

Learning Resources	**Metallography: Principles and Practice,** George F. Vander Voort ***Principles of Metallographic Laboratory Practice***, Leonard E. Samuels **Metallography and Microstructures** (ASM Handbook, Vol. 9), George F. Vander Voort **In-house Laboratory Manuals** **Virtual Labs** (NPTEL/VTU Virtual Lab)

Course Code	MM2173N	Course Name	Transport Phenomena and Rate Processes Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		**Data Book / Codes/Standards**	Nil

Course Objectives	The primary objective of this course is to equip students with computational tools that they can apply in solving metallurgical/materials industry-oriented problems involving heat, mass and momentum transfer

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Review of vectors and tensors: Dot, cross and dyadic product of two vectors	3	Students will learn to do basic vector calculations using MATLAB
II	Review of ordinary differential equations: Forward and Backward Euler Method, Mid-point Method and Classical Runge-Kutta Method	3	Students will learn to solve ordinary differential equations using MATLAB
III	Review of partial differential equations	3	Students will learn to solve partial differential equations using MATLAB
IV	Simulation of laminar fluid flow on a flat plate	3	Students will learn to set up a simple laminar fluid flow model in COMSOL Multiphysics.
V	Simulation of fully developed fluid flow between two parallel plates	3	Students will learn the effect of changing boundary conditions for simple laminar fluid flow models in COMSOL Multiphysics.
VI	Simulation of heat conduction in one dimension through a layered wall	3	Students will learn to set up a simple one-dimensional heat conduction model in COMSOL Multiphysics.
VII	Simulation of heat conduction in an insulated pipe	3	Students will learn to set up a simple heat conduction and convection model in COMSOL Multiphysics.
VIII	Simulation of diffusion in one dimension (Carburization)	3	Students will learn how to set up a simple diffusion model in COMSOL Multiphysics.
IX	Estimation of activation energy for a first-order reaction	3	Students will learn how to calculate activation energy from the chemical kinetics data using Microsoft Excel

Course Outcome	CO1: On completion of this course, the student should be able to appreciate the importance of reliable input, in the form of properties, initial and boundary conditions, to material processing software. CO2: The student should be able to acquire basic skill in using software like MATLAB, COMSOL Multiphysics and Microsoft Excel in solving engineering problems.

Learning Resources	Text Book(s): - Transport Phenomena, R. B. Bird, W. E. Stewart, E. N. Lightfoot, Wiley - A Textbook of Metallurgical Kinetics, A. Ghosh and S. Ghosh, PHI Learning Pvt. Ltd. Reference Book(s): - Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers - COMSOL Multiphysics Manuals

Syllabus: Fourth Semester

Course Code	MM2201N	Course Name	Deformation Behaviour of Materials	Course Category	PC	L	T	P
						3	1	0

Pre-requisite Courses	Engineering Mathematics – I, II	Co-requisite Courses	Nil	Progressive Courses	Mechanical Testing of Materials, Metal Forming Technology
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	The primary objective of this foundational course is to introduce (i) mathematical theories of elastic and plastic deformation, (ii) the theory of dislocations, and (iii) how microstructural parameters affect the macroscopic mechanical strength of materials

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to deformation behaviour:** Concept of stresses and strains; engineering and true stress/strain; analysis of simple tension test data	6	Students will get a basic understanding of stresses and strains
II	**Theory of Elasticity:** State of stress at a point, State of plane stress, Principal stresses and planes, Mohr's circle of stress (2D), State of stress in 3D; Strain at a point: Definition of normal and shear strains; Concept of hydrostatic stress and stress deviator; Elastic stress-strain relationships; Elastic strain energy	6	Students will be able to perform basic calculations on elastic deformation of materials
III	**Theory of Plasticity:** Flow Curve, power-law relationship; Relationship between true stress and engineering stress; Yield criteria for ductile metals: Von Mises' criterion and Tresca criterion; Combined stress tests; Yield locus; Octahedral shear stress and shear strain; Invariants of stress and strain; Plastic stess-strain relationships: Levy-Mises equations and Prandtl-Reuss equations	8	Students will be able to solve problems associated with permanent deformation of materials
IV	**Plastic deformation of a single crystal:** Review of crystal planes and directions; Point defects; Line defects; Deformation by slip; Critically Resolved Shear Stress; Deformation by twinning; Stacking faults; Generalized flow curve for a FCC single crystal	6	Students will be able to understand concepts of slip systems and will have a basic understanding of material defects, including dislocations
V	**Dislocation theory**: Edge, screw and mixed dislocations; Burgers vector and Burgers circuit; Peierl-Nabarro stress; Cross-slip of screw dislocations; Dislocation reactions; Dislocations in FCC lattice: Partial dislocations, Lomer-Cottrell barrier; Dislocations in HCP lattice and in BCC lattice; Stress-field of	8	Students will develop an in-depth understanding of the theory of dislocations

	dislocations; Elastic strain energy of dislocations; Force between dislocations; Dislocation climb; Intersection of Dislocations; Sources of dislocations; Multiplication of dislocations; Interaction between a dislocation and a point defect		
VI	**Strengthening Mechanisms**: Grain boundaries; Equi-cohesive temperature; Hall-Petch relationship; Yield Point phenomenon; Strain-aging; Solid-solution strengthening; Strengthening from fine particles: Age hardening; Fibre strengthening; Martensite strengthening; Ausforming; Strain hardening: cold-worked structure; Effect of annealing on cold-worked metal; Bauschinger effect	8	Students will be able to understand how microstructural parameters affect the mechanical strength of a metal/alloy

Course Outcome	CO1: On completion of this course, students should be able to define and calculate various stress and strain components in elastic regime CO2: Students shuld be able to calculate limiting conditions that lead to permanent deformation CO3: Students should be able to define slip systems, twin systems and dislocation interactions in FCC, BCC and HCP crystals CO4: Students should be able to make simple correlations between various microstructural parameters and processing conditions to the strength of a metal/alloy.

Learning Resources	Text Book(s): - Mechanical Metallurgy, G.E. Dieter, McGraw Hill Reference Book(s): - Mechanical Behavior of Materials, T. H. Courtney, McGraw Hill - Deformation and Fracture Mechanics of Engineering Materials, R. W. Hertzberg, R. P. Vinci, J. L. Hertzberg, Wiley

Course Code	MM2202N	Course Name	Extractive Metallurgy	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	
	• To introduce students to the fundamental principles and processes of extractive metallurgy, including mineral dressing, pyrometallurgy, hydrometallurgy, and electrometallurgy. • To develop an understanding of the application of various metallurgical processes and their flow sheets for metal extraction. • To equip students with skills to perform material and heat balance calculations in extractive metallurgy processes.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction: Important ores and minerals and their occurrence in India; Importance of mineral-dressing	2	Understand the significance of mineral dressing and identify key ores and minerals in India.
II	Mineral dressing: Various Comminution Processes - theories involved, brief description and applications, various concentration techniques and their applications, mineral dressing circuits and flowsheets	10	Explain comminution and concentration techniques and analyze mineral dressing circuits and flowsheets.
III	Unit Processes in Pyrometallurgy: Introduction, Calcination, Roasting, Agglomeration, Reduction smelting, Matte smelting, Flash smelting, and Converting	10	Describe pyrometallurgical processes and their applications in metal extraction.
IV	Unit Processes in Hydrometallurgy: Introduction, Leaching, Purification of Leach Liquor, Solvent Extraction and Ion-exchange Processes, Techniques of Metal Recovery from Aqueous phase	8	Understand hydrometallurgical processes and techniques for metal recovery from aqueous solutions.
V	Unit Processes in Electrometallurgy: Introduction, Faraday's laws of electrolysis, concept of overvoltage, limiting current density, Electrowinning and Electro-refining with reference to copper, zinc, and aluminium	8	Explain electrometallurgical principles and their application in electrowinning and electro-refining of metals.
VI	Flow sheets and numerical calculations: Flow-charts, Material balance and Heat balance	4	Develop and analyze flow sheets and perform material and heat balance calculations for metallurgical processes.

Course Outcome	
	• Students will be able to explain the principles and processes of extractive metallurgy, including mineral dressing, pyrometallurgy, hydrometallurgy, and electrometallurgy. • Students will develop the ability to analyze and design process flow sheets for metal extraction.

	• Students will acquire skills to perform material and heat balance calculations in metallurgical operations.

Learning Resources	Principles of Extractive Metallurgy - A. Ghosh, and H. S. Ray Non-ferrous Extractive Metallurgy - H. S. Ray, R. Sridhar, and K. C. Abraham Extractive Metallurgy Principles - T. Rosenqvist Extractive Metallurgy - J. Gilchrist

Course Code	MM2203N	Course Name	**Heat Treatment Technology**	Course Category	**PC**	**L**	**T**	**P**
						3	**0**	**0**

Pre-requisite Courses	Nil	**Co-requisite Courses**	Nil	**Progressive Courses**	1. Mechanical Testing of Materials
Course Offering Department		Metallurgy and Materials Engineering		**Data Book / Codes/Standards**	ASTM Hand Book

Course Objectives	
	➢ To learn the scientific principles behind phase transformations that govern heat treatment processes. ➢ To study how different heat treatment methods affect the microstructure and mechanical properties of metals and alloys. ➢ To develop the ability to select and implement appropriate heat treatment processes for specific engineering applications and performance requirements.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction and principles of Heat treatment of steels:** formation of austenite (kinetics of formation of austenite, roll of austenite grain size etc.), decomposition of austenite (different types of time-temperature-transformation and continuous cooling transformation diagrams, pearlitic, bainitic, Martensitic transformation)	5	Students will understand austenite formation, TTT/CCT diagrams, and phase transformations in steels to analyze microstructure and mechanical property changes
II	**Heat treatment processes:** Annealing (Full, Homogenising, Spheroidisation and Stress-relieving annealing); Normalising; Hardening (Objective, Austenitizing temperature and Internal stresses), Quenching Mediums and Methods, Retained austenite and Defects in hardening; Tempering of steels: Aims and stages of tempering, Effects of Carbon and alloying elements, Tempering of alloy steels and Multiple tempering, Embrittlement during tempering. Principles and processes- austempering, martempering, patenting, ausforming etc. Heat treatment-Microstructure-Property correlations.	8	Students will know various heat treatment processes and analyse their influence on steels' microstructure, mechanical properties, defects, and transformation behaviour.
III	**Hardenability:** Significance, Critical and ideal critical diameter, different hardenability test methods, Factors affecting hardenability. Characteristics of quenchants, Different quenching media. Development of residual stresses, Quench cracking.	6	Students will evaluate the hardenability concepts, quenching media characteristics, and analyse factors affecting hardenability, residual stresses, etc., in steels.
IV	**Thermo-mechanical treatments:** Principles and processes- Controlled rolling, Hot-Cold working, Ausforming, Isoforming, Marstraining, Cryoforming etc. Thermo-mechanical treatment of ferrous and non-ferrous alloys.	5	Student will understand principles and processes of thermo-mechanical treatments and their applications on ferrous and non-ferrous alloys for improved properties.
V	**Age-Hardening**: Types, processes and sequence of precipitates, Mechanism and kinetics of precipitation for ferrous and non-ferrous alloys.	5	Students will understand age-hardening precipitation processes for improved material properties.
VI	**Heat treatment of different types of ferrous and nonferrous metals and alloy:** Classifications, Role of major alloying elements, heat treatment process and microstructural changes; Heat treatments of general	7	Students will learn about the heat treatment, alloying effects, and microstructural

	engineering steels: Spring, Bearing steels, Tool steels, HSLA steel and Maraging steels, Dual phase steels, Stainless steels, cast Iron, Heat Treatments of Al-alloys, Cu-alloys and Ti-alloys etc.		and property changes for materials.
VII	**Surface hardening of steels:** Classification, Principles, Case carburizing (solid, liquid and gas), Nitriding, Cyaniding, Carbonitriding, Plasma nitriding, Selective hardening, Flame hardening, Induction hardening, Laser hardening etc. Measurement of case depth and its relation with time and temperature.	4	Students will able to comprehend classification, principles, and techniques of surface hardening in steels, including case depth measurement.
VIII	**Design for heat treatment** Heat treatment furnaces- their temperature and atmosphere control; Defects in heat treated parts - Causes and remedies; Automation.	2	Students will learn about heat treatment furnace control, design considerations, defects in heat-treated parts, and causes and remedies.

Course Outcome	➢ Students will understand the importance of selecting appropriate heat treatment processes to achieve desired material properties and performance. ➢ Students will learn various heat treatment techniques and their role in modifying microstructure and mechanical behaviour. ➢ Students can correlate heat treatment methods with resulting microstructural changes and material properties. ➢ Students will recognise heat treatment as a key tool for optimising steels and tailoring properties for specific engineering applications.

Learning Resources	1. Heat Treatment: Principles and Techniques, 2nd edition, Kindle Edition by Ashok Rajan, T.V. Sharma, C.P. Sharma. 2. C R Brooks, Principles of the Heat Treatment of Plain Carbon and Low Alloy Steels, ASM Internationa. 3. B. Zakharov, Heat Treatment of Metals, CBS Publishers 4. G. Krauss,Steels, Processing, Structure and Performance, ASM International 5. K E Thelning, Steel and Its Heat Treatment, Butterworth

Course Code	MM2204N	Course Name	Materials Characterization	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	Co-requisite Courses	*NIL*	Progressive Courses	
Course Offering Department		***Metallurgy and Materials Engineering***		Data Book / Codes/Standards	

Course Objective	
	● To introduce the fundamental principles and instrumentation of various materials characterization techniques. ● To develop the ability to select appropriate techniques for analyzing structure, composition, and properties of materials. ● To provide theoretical understanding of imaging, diffraction, and spectroscopic methods for different length scales (micro to nano). ● To train students in interpreting experimental data and correlating it with material behavior and processing. ● To emphasize the integrated application of multiple techniques through real-world case studies.

Module	Syllabus	Duration (class-hour)	Module Outcome
1	**Introduction to Materials Characterization**: Classification of techniques – structural, surface, chemical, and mechanical; relevance to metallurgical applications.	2	Understand the need and scope of materials characterization techniques across different material classes.
2	**Optical Microscopy**: Basic principles, resolution, contrast mechanisms, sample preparation, and metallographic analysis.	3	Apply optical microscopy for microstructural analysis and understand image formation and limitations.
3	**Phase Contrast, Fluorescence & Confocal Microscopy**: Contrast enhancement, fluorescence imaging principles, laser scanning in confocal microscopy.	6	Compare and apply advanced optical techniques for transparent and functional materials characterization.
4	**Scanning Electron Microscopy (SEM)**: Electron-matter interactions, secondary and backscattered electrons, detectors, image formation, and applications.	6	Analyze surface morphology with SEM; understand contrast mechanisms and electron signal generation.
5	**Transmission Electron Microscopy (TEM)**: Working principle, image and diffraction contrast, selected area diffraction patterns, sample preparation.	6	Interpret crystal structures and defects using high-resolution TEM and diffraction techniques.

6	**X-ray Diffraction (XRD)**: Bragg's law, powder diffraction, phase analysis, lattice parameter determination, crystallite size estimation.	6	Apply XRD for phase identification and structural analysis; calculate crystallite size and lattice strain.
7	**Scanning Probe Microscopy (AFM & STM)**: Working principle, tip-sample interaction, imaging modes, resolution, and topographical mapping.	4	Use AFM/STM to characterize surface features at the nanoscale and understand instrumentation.
8	**Fourier Transform Infrared Spectroscopy (FTIR)**: IR absorption, molecular vibrations, instrumentation, and qualitative chemical analysis.	3	Analyze functional groups and chemical bonds in materials using FTIR spectra.
9	**Raman Spectroscopy**: Raman effect, instrumentation, vibrational modes, applications to crystalline and nanostructured materials.	3	Interpret Raman spectra to analyze vibrational and structural characteristics of materials.
10	**Integrated Characterization Approach & Case Studies**: Correlation of data from multiple techniques; practical problem-solving and data interpretation.	3	Develop integrated understanding of characterization; solve case-based material problems using multi-technique data.

Course Outcome	● Explain the working principles and operational parameters of major materials characterization techniques including microscopy, diffraction, and spectroscopy. ● Interpret optical and electron microscopy images to analyze microstructural features of materials. ● Analyze diffraction data (XRD, TEM) to determine crystal structure, phase identity, and crystallographic parameters. ● Apply spectroscopic techniques (FTIR, Raman) for identifying chemical bonding and molecular structure. ● Correlate information obtained from multiple techniques to solve complex characterization problems and assess material performance. ● Demonstrate a systematic approach to materials analysis through case studies and data interpretation exercises.

Learning Resources	1. Elements of X-ray Diffraction; B.D. Cullity and S.R. Stock; Pearson Education, 3rd Edition 2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods; Yang Leng; Wiley-VCH, 2nd Edition; 3. Transmission Electron Microscopy: A Textbook for Materials Science; David B. Williams and C. Barry Carter; Springer, 2nd Edition

Course Code	MM2271N	Course Name	Deformation Behaviour of Materials Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	The primary objective of this course is to equip students with computational tools that they can apply in calculation of stresses and strains during elastic and plastic deformation

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Analysis of tensile test data** to evaluate elastic modulus, 0.2% yield strength, ultimate tensile strength and fracture strength of metals	3	The student will be able to calculate common mechanical properties from the tensile test data using Microsoft Excel
II	**Analysis of tensile test data** to evaluate strength coefficient and strain hardening coefficient assuming power law strain hardening	3	The student will be able to calculate strain hardening parameters from the flow curve using Microsoft Excel.
III	**Analysis of two-dimensional state of plane stress**: Transformation of stresses, evaluation of principal stresses, principal directions, maximum shear stress, angle of plane for maximum shear stress, construction of Mohr's circle of stress (2D)	3	The student will be able to analyze a 2-D state of plane stress and construct a Mohr's circle of stress using MATLAB
IV	**Analysis of three-dimensional state of stress**: Evaluation of invariants of stress, principal normal stresses, principal directions, principal shear stress, hydrostatic stress, deviatoric stress, and J_2	3	The student will be able to analyze a 3-D state of stress and calculate the principal stresses and directions using MATLAB
V	**Analysis of three-dimensional state of strain**: Evaluation of strain tensor and rotation tensor from a given displacement vector, evaluation of volumetric strain, hydrostatic strain, and strain deviator	3	The student will be able to evaluate strain tensor and rotation tensor from a given displacement field using MATLAB
VI	**Evaluation of elastic strains from elastic stresses** and vice-versa for isotropic elastic solids, evaluation of shear modulus and bulk modulus, evaluation of elastic strain energy	3	The student will be able to evaluate elastic stress and strain components for a linearly elastic solid
VII	**Finite element simulation of elastic deformation** of a linearly elastic isotropic solid	3	The student will be able to generate a simple model for a linearly elastic solid in COMSOL Multiphysics or ABAQUS and plot the stress-strain response.
IX	**Finite element simulation of elasto-plastic deformation** of an isotropic solid	3	The student will be able to generate a simple model for a an elastoplastic solid in COMSOL Multiphysics or

			ABAQUS and plot the equivalent plastic stress – equivalent plastic strain response.
X	**Study of stress fields around edge dislocations**, interaction of dislocations	3	The student will be able to plot the stress field around edge dislocations and study how edge dislocations interact using MATLAB

Course Outcome	CO1: On completion of the course, the student should be able to write simple codes to calculate stress and strain components CO2: The student should be able to simulate stress-strain response of a linearly elastic and elastoplastic solids. CO3: The student should be able to plot and visualize stress fields around dislocations CO4: The student should get acquainted with commercial finite element software for simulating deformation response of materials

Learning Resources	Text Book(s): - Mechanical Metallurgy, G.E. Dieter, McGraw Hill Reference Book(s): - Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers - COMSOL Multiphysics Manuals

Course Code	MM2272N	Course Name	Extractive Metallurgy Lab	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	• To provide hands-on experience in mineral processing and hydrometallurgical operations. • To analyze the design, operation, and efficiency of size-reduction and separation equipment. • To evaluate reaction kinetics in hydrometallurgical processes like cementation and leaching.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Assignment on comminution circuits: crushing/grinding, equipment, open/close circuits	3	Analyze circuit configurations and equipment selection for ore comminution.
II	Study of design/operation: (i) Jaw crusher	3	Compare performance parameters of primary crushers and their applications.
III	Study of design/operation: Ball mill	3	Demonstrate grinding mechanisms and optimize ball mill operations.
IV	Study of design /operation of froth floatation	3	Demonstrate the principles of froth flotation to achieve selective mineral separation.
V	Study of design/operation: Wilfley table	3	Apply gravity separation principles using Wilfley tables for mineral concentration
VI	Sieve analysis: Plotting cumulative particle distribution curves	3	Interpret particle size data and assess comminution efficiency.
VII	Kinetics of copper cementation from solutions using zinc/iron	6	Determine reaction rates and factors influencing cementation efficiency
VIII	Kinetics of leaching oxide metals in dilute acidic solutions	6	Model leaching kinetics and evaluate acid concentration effects

Course Outcome	• Operational Proficiency: Demonstrate safe handling of crushers, grinders, and separators. • Data Analysis: Interpret particle distribution curves and kinetic data from hydrometallurgical experiments. • Process Optimization: Recommend improvements in comminution circuits and leaching/cementation parameters.

Learning Resources	Process selection in Extractive Metallurgy by Peter Hayes, SBA Pulications Principles of Extractive Metallurgy, Vol.1 by Fathi Habashi, Gordon and Breach, New York Principles of Mineral Dressing by A. M. Gaudin, McGrew Hill Book Company Mineral Processing by S. K. Jain, CBS publishers and Distributors Pvt. Ltd

Course Code	MM2273N	Course Name	Heat Treatment Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Mechanical Testing of Materials
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	ASTM Handbook

Course Objectives	
	➢ Gain practical experience in performing various heat treatment processes such as annealing, hardening, tempering, and surface hardening. ➢ Understand the relationship between heat treatment parameters, microstructural evolution, and mechanical properties of metals and alloys. ➢ Develop skills in using laboratory equipment for heat treatment and material characterization. ➢ Correlate theoretical knowledge with experimental observations to reinforce concepts of phase transformations and material behavior.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Operation, Control of Heat Treatment Furnaces, temperature calibration of heat treatment furnaces	3	Operate and calibrate heat treatment furnaces; control temperature cycles; ensure accuracy and process reliability.
II	Heat treatment of plain carbon (0.3, 0.55, 0.8 and 1.1 wt.% C): Annealing, normalizing, hardening and tempering. Evaluation of their microstructure and hardness.	3	Heat treat plain carbon steels; evaluate microstructure and hardness after annealing, normalizing, hardening, tempering.
III	Heat treatment of eutectoid steel at different cooling rate and evaluation of microstructure and hardness.	3	Heat treat eutectoid steel; evaluate microstructure and measure hardness.
IV	Recovery, recrystallization and grain growth of Copper and copper alloy	6	Study recovery, recrystallization, and grain growth in copper alloys.
V	Hardenability measurement of alloy steel by Jominy End Quench method	3	Determine hardenability of alloy steel using Jominy end-quench method.
VI	Heat treatment of high speed steel and Duel phase steel and evaluation hardness and microstructure	6	Heat treat high-speed and dual-phase steels; evaluate hardness and microstructure.
VII	Malleablizing heat treatment of white cast iron	3	Perform malleablizing of white cast iron; analyze microstructure and hardness.
VIII	Case hardening treatment	3	Apply case hardening; evaluate surface hardness and microstructure changes.
IX	Microstructure and hardness evaluation of TMT rebar	6	Evaluate microstructure and hardness of TMT rebars after heat treatment.

X	Viva Voce	3	

Course Outcome	➢ Understand and apply various heat treatment processes such as annealing, normalizing, quenching, and tempering. ➢ Correlate microstructural changes with mechanical properties after different heat treatments. ➢ Operate furnaces, hardness testers, and metallographic equipment safely and effectively. ➢ Analyze and interpret experimental data to evaluate the effects of heat treatment on different alloys.

Learning Resources	1. G. Krauss,Steels, Processing, Structure and Performance, ASM International 2. Laboratory Handouts

Course Code	MM2274N	**Course Name**	Materials Characterization Lab	**Course Category**	PC	L	T	P
						0	0	3

Pre-requisite Courses	*NIL*	**Co-requisite Courses**	*NIL*	**Progressive Courses**	*Nil*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*Nil*

Course Objective	• To provide hands-on experience with material characterization equipment and techniques. • To teach experimental design, data acquisition, and interpretation related to material structure, composition, and morphology. • To bridge the gap between theoretical knowledge and real-world applications of characterization tools.

Module	Syllabus	Duration (lab-hour)	Module Outcome
I	**Introduction & Safety Briefing**: Overview of characterization techniques, lab safety, and sample handling protocols.	3	Understand safety practices and prepare for advanced instrumentation labs.
II	**Metallographic Preparation and Optical Microscopy – I**: Cutting, mounting, grinding, and polishing of metallic samples (demonstration); introduction to microstructure imaging.	3	Understand standard metallographic preparation and correlate surface quality with image clarity.
III	**Metallographic Preparation and Optical Microscopy – II**: Etching and observation under optical microscope; grain size estimation and phase contrast (hands-on image analysis).	3	Interpret micrographs and extract microstructural information using standard measurement techniques.
IV	**SEM Demonstration and Data Analysis**: Demonstration of SEM operation, surface imaging of fractured/polished samples; contrast mechanisms; hands-on image analysis.	6	Analyze SEM images to evaluate morphology and interpret failure surfaces.
V	**XRD Demonstration and Phase Identification**: Bragg's law, data collection (demo), phase identification using database software.	3	Use XRD data to identify phases and calculate interplanar spacing.
VI	**XRD Data Interpretation**: Estimation of crystallite size and lattice strain using Scherrer formula; peak indexing and profile analysis.	3	Quantify crystal structure parameters and grain size from XRD patterns.

VII	**TEM Data Analysis**: Interpretation of TEM images, dislocations, and selected area electron diffraction (SAED) patterns (no hands-on operation).	6	Analyze crystallographic information and lattice defects using TEM data.
VIII	**AFM Demonstration and Image Analysis**: Working principle, scanning modes, surface topography, and roughness interpretation.	3	Interpret AFM images and analyze nanoscale features like surface height and morphology.
IX	**FTIR Spectroscopy**: Vibrational modes, functional group identification from FTIR spectra of polymers and oxides.	3	Assign IR peaks to specific bonds and identify materials based on FTIR spectra.
X	**Raman Spectroscopy**: Analysis of Raman spectra of oxides, carbon materials; phase detection and structural defects.	3	Use Raman spectral features to interpret structure, crystallinity, and disorder.
XI	**Integrated Characterization & Report Writing:** Correlation of data from multiple techniques for a selected sample; preparing a technical report.	6	Integrate multiple experimental results into a coherent report demonstrating interpretation and analysis.

Course Outcome	● Basic knowledge about operating key characterization instruments like XRD, SEM, AFM, and spectrometers. ● Prepare samples and perform measurements. ● Analyze and interpret real experimental data. ● Choose suitable characterization methods for various material systems.

Learning Resources	➢ Elements of X-ray Diffraction; B.D. Cullity and S.R. Stock; Pearson Education, 3rd Edition ➢ Materials Characterization: Introduction to Microscopic and Spectroscopic Methods; Yang Leng; Wiley-VCH, 2nd Edition; ➢ Transmission Electron Microscopy: A Textbook for Materials Science; David B. Williams and C. Barry Carter; Springer, 2nd Edition

Syllabus: Fifth Semester

Course Code	MM3101N	Course Name	**Mechanical Testing of Materials**	Course Category	**Program Core (PC)**	L	T	P
						3	**0**	**0**

Pre-requisite Courses	*NIL*	Co-requisite Courses	*NIL*	Progressive Courses	*NIL*
Course Offering Department		**Metallurgy and Materials Engineering**		Data Book / Codes/Standards	ASTM Standards

Course Objective	*To impart fundamental understanding of mechanical behavior and testing principles of materials under various loading conditions, enabling students to evaluate and interpret mechanical properties through standard testing methods for material selection, design, and performance assessment.*

Module	Syllabus	Duration (hour)	Module Outcome
I	**Introduction to Mechanical Testing** Importance and objectives of mechanical testing; Classification of mechanical properties; Standardization and testing protocols (ASTM, ISO)	4	Gain a foundational understanding of the significance of mechanical testing, the classification of mechanical properties, and the application of standard testing protocols for consistent and reliable material evaluation.
II	**Hardness** Classification; Scratch hardness -Mohs scale, Rebound hardness, Indentation hardness - Principles and Practices of Brinell, Vickers, Knoop, Rockwell, Meyer hardness testing; Macro- and micro-hardness; Nanoindentation; Oliver-Pharr method; Comparison of various indenters; Indentation Size Effect; Indentation Fracture Toughness; Relationships between hardness and strength.	6	Understand the principles of various hardness testing methods—including scratch, rebound, and indentation techniques—compare macro, micro, and nanoindentation approaches, and correlate hardness with material strength, toughness, and the effects of indentation size.
III	**Tensile** Elastic, anelastic and plastic properties of materials; Tensile properties; Engineering and true stress-strain diagrams; Plastic instability; Factors affect stress-strain response; The relations between stress, strain, strain rate and temperature of engineering materials; Superplasticity; Types of failure; Ductile and brittle fracture; Transgranular and Intergranular fracture; Micromechanisms of failure.	6	Understand the deformation behavior of materials under tensile loading, analyze stress-strain relationships and failure mechanisms, and evaluate the influence of internal factors like microstructure and external variables on tensile properties.
IV	**Compression, Torsion and Bending** Mechanical properties in compression, torsion and bending; Stresses at large plastic stress; Compression tests; Solid and Tubular torsional tests; Shear stress-shear strain; 3-point and 4-point bending tests; Bending strength; Types of failure; Hot deformation.	6	Develop a comprehensive understanding of material behavior under compression, torsion, and bending, including testing methods, failure modes, and the effects of temperature and strain rate on hot deformation.

V	**Impact Toughness** Effects of strain rate on mechanical properties; impact tests -Charpy and Izod; Instrumented Charpy; Various transition temperatures and their significance; Effects of metallurgical factors on transition temperature; Drop weight test, etc.	4	Gain a comprehensive understanding of impact toughness, standard testing methods, transition temperature, failure mechanisms, and the metallurgical factors that control the ductile-to-brittle transition behavior.
VI	**Fatigue** Importance; Dynamic loading; Classification of high cycle and low cycle fatigue; The S-N curve; Statistical nature of fatigue; Effects of mean stress, stress range and notch; Criteria of fatigue failure; Design for fatigue; Cyclic stress-strain curve; Strain-life equation; Factors influencing fatigue properties; Features of fatigue failure; Initiation fatigue crack, Different stages of fatigue crack propagation; Paris' law; Improvement of fatigue strength via controlling of metallurgical variables.	8	Build a deep understanding of fatigue behavior under dynamic loading conditions; distinguish between high-cycle and low-cycle fatigue; interpret S-N curves and strain-life relationships; analyze fatigue crack initiation and propagation using Paris' law; and assess the impact of design parameters and metallurgical factors on fatigue performance and strategies for improving fatigue life.
VII	**Creep** Deformation at elevated temperature; Creep curve; Effects of temperature and stress; Mechanisms of creep deformation; Deformation mechanisms map; Stress rapture test; Design of creep resistance materials.	4	Develop an understanding of time-dependent deformation at elevated temperatures, conduct and interpret creep tests, identify deformation mechanisms using creep maps, and apply this knowledge to design and select materials resistant to creep.
VIII	**Non-destructive testing methods** Principle, practice, advantage, limitation and applications of dye penetrant, magnetic particle, ultrasonic, radiography, Eddy current and acoustic emission methods.	4	Understand the principles, procedures, advantages, limitations, and applications of key non-destructive testing methods for effective evaluation of structural integrity.
	Total	**42**	

Course Outcome	On completion of the course, the students should be able to **CO1:** Explain and apply standard mechanical testing methods to evaluate material properties such as hardness, tensile strength, impact toughness, fatigue, and creep. **CO2:** Interpret stress-strain behavior, failure mechanisms, and deformation characteristics under various loading conditions. **CO3**: Select appropriate destructive and non-destructive testing techniques for assessing material performance and integrity.

Learning Resources	● Dieter, G.E., *Mechanical Metallurgy*. 3rd ed., McGraw-Hill, 1986. ● Gdoutos, E.E. and Konsta-Gdoutos, M.S., *Mechanical Testing of Materials*. Springer Nature Switzerland, 2024. ● Ashby, M.F. and Jones, D.R.H., *Engineering Materials 1: An Introduction to Properties, Applications and Design*. 4th ed. Oxford, 2012. ● Bhargava, A.K., Sharma, C.P. and Singh, L.P., 2012. *Mechanical behaviour and testing of materials*. PHI Learning, 2012 ● ASTM International, *Annual Book of ASTM Standards*. West Conshohocken, PA: ASTM International, 2023.

Course Code	MM3102N	Course Name	Iron and Steel Making	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy an Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	
	▪ To provide students with a thorough understanding of the fundamental principles and industrial practices involved in the production of iron and steel. ▪ To prepare students for careers in the steel industry and related sectors, and to enable them to contribute to innovations in sustainable and efficient steel production.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to Iron and Steel Industry:** History and significance of iron and steel, Overview of global and national steel production, Classification of iron and steelmaking processes	5	Student will understand the historical development and economic importance of iron and steel.
II	**Raw Materials for Iron Making:** Iron ores and agglomeration (sintering, pelletizing), Coke making and properties, Fluxes and slag chemistry	5	Student will be able to evaluate the role of coke and fluxes in blast furnace operations and the impact of raw material characteristics on process efficiency.
III	**Blast Furnace Ironmaking:** Structure and zones of a blast furnace, Reactions and heat/mass transfer, Slag-metal reactions and tapping, Modern trends in blast furnace operation.	5	Student will be able to analyze chemical reactions and thermal processes in blast furnace ironmaking.
IV	**Alternative Ironmaking Technologies:** Direct Reduced Iron (DRI) processes (MIDREX, HYL), Smelting reduction processes (COREX, FINEX), Environmental and economic considerations	6	Student will understand the principles behind DRI and smelting reduction.
V	**Primary Steelmaking:** Basic Oxygen Furnace (BOF) process, Electric Arc Furnace (EAF) process, Reactions, slag-metal interactions, and control.	5	Student will understand the thermodynamics and kinetics of primary steelmaking. Student will be able to differentiate between BOF and EAF steelmaking routes.
VI	**Secondary Steelmaking (Ladle Metallurgy):** De-oxidation, desulfurization, and inclusion control, Vacuum degassing and ladle furnace operation, Alloying process.	5	Student will be able to explain refining techniques used in secondary steelmaking and interpret process control strategies to meet steel specifications.
VII	**Continuous Casting Process:** Principles of continuous casting, Mold design, heat transfer,	5	Student will be able to describe the continuous casting process and its advantages.

	and defects, Final product properties and control		
VIII	**Environmental, Energy and sustainability Aspects:** Emissions and pollution control in iron and steel plants, Energy conservation measures, Waste recycling, Circular Economy, Hydrogen-Based Ironmaking.	6	Student will be able to assess environmental impacts of iron and steelmaking, and apply principles of sustainability in process design.
	Total	**42**	

Course Outcome	1. Student will be able to explain the principles, processes, and equipment used in iron and steel production, including blast furnace ironmaking and various steelmaking routes. 2. Student will be able to analyze the roles and characteristics of raw materials (iron ore, coke, and fluxes) and their influence on furnace operation and product quality. 3. Student will be able to evaluate chemical reactions and thermodynamics involved in iron reduction, steel refining, and slag-metal interactions. 4. Student will be able to interpret process parameters and control strategies used in primary and secondary steelmaking, and continuous casting process to meet product specifications. 5. Student will be able to evaluate strategies for sustainable steel production technologies and hydrogen-based steel production

Learning Resources	1. Ghosh, Ahindra, and Amit Chatterjee. Iron making and steelmaking: theory and practice. PHI Learning Pvt. Ltd., 2008. 2. Dutta, Sujay Kumar, and Yakshil B. Chokshi. Basic concepts of iron and steel making. Springer Nature, 2020. 3. Turkdogan, E. T., and R. J. Fruehan. "Fundamentals of iron and steelmaking." The Making, Shaping and Treating of Steel, Steelmaking and Refining Volume, 11th ed., RJ Fruehan, ed., AISE Steel Foundation, Pittsburgh 11 (1998): 125-126. 4. Pal, Snehanshu, Anshuman Patra, and Prabodh Ranjan Padhee. Process Modeling for Steel Industry. IK International Pvt Ltd, 2018.

Course Code	MM3103N	Course Name	Joining of Materials	Course Category	PC	L	T	P
						3	1	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		**Data Book / Codes/Standards**	Nil

Course Objectives	• To provide students with a comprehensive understanding of various material joining processes, including welding, brazing, soldering, with emphasis on their metallurgical implications. • To enable students to analyze the design, operation, and performance of joints in engineering applications. • To equip students with skills to evaluate weld imperfections and apply testing methods for quality assurance in material joining.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Introduction to Joining Processes : Overview of joining techniques (welding, brazing, soldering, adhesive bonding), classification based on energy source and material interactions, importance in metallurgical applications, factors affecting joint quality.	3	Understand the classification and significance of joining processes in metallurgical applications
II	Physics of Welding - Welding Arc and their types, structure, mechanism, stability and characteristics, Mechanism of Arc blow, its effect and remedies. Types of metal transfer and forces affecting it	6	Explain the principles of welding processes
III	Arc Welding Processes : Design and operation of arc welding techniques: (i) Shielded Metal Arc Welding (SMAW), (ii) Gas Metal Arc Welding (GMAW/MIG), and (iii) Gas Tungsten Arc Welding (GTAW/TIG).	6	Analyze the design and operational parameters of arc welding processes and their applications.
IV	Resistance welding: Spot, seam, projection welding	4	Understand the principles of Resistance welding
V	Solid-State Welding Processes : Principles and applications of solid-state welding: (i) Friction Welding, (ii) Friction Stir Welding, and (iii) Ultrasonic Welding,	6	Evaluate the mechanisms and applications of solid-state welding for dissimilar materials.
VI	Brazing and Soldering : Fundamentals of brazing and soldering, filler materials, fluxes, joint design, and applications in dissimilar material joining.	4	Understand the principles of brazing and soldering and their role in joining dissimilar materials.
VII	Advanced Joining Techniques	7	Understand advanced joining techniques and analyze

	: Introduction to advanced processes: (i) Laser Beam Welding, (ii) Electron Beam Welding; (iii) Plasma arc welding, (iv) Explosive welding		microstructural changes in welded joints.
VIII	Weld Imperfections and Testing : Types of weld imperfections (porosity, cracks, inclusions), non-destructive testing (NDT) methods (radiography, ultrasonic testing, magnetic particle testing), and destructive testing for joint strength.	6	Identify weld imperfections and apply appropriate testing methods to ensure joint quality.

Course Outcome	● Students will be able to select and apply appropriate joining techniques for specific materials and applications, considering metallurgical and mechanical properties. ● Students will gain proficiency in evaluating joint quality through testing methods and analyzing microstructural changes in welded joints. ● Students will understand the principles, design, and operational parameters of various joining processes, enabling them to address challenges in materials engineering.

Learning Resources	Joining of Materials and Structures: From Pragmatic Process to Enabling Technology,Robert W. Messler Jr., Butterworth-Heinemann; 1 edition Welding, D. Greary and Rex Miller, McGraw-Hill Education; 2 editions Welding: Principles and Applications, Larry F. Jeffus, Thomson Delmar Learning, 5th edtion

Course Code	MM3104N	Course Name	Metal Forming Technology	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Deformation Behaviour of Materials	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	This course aims to give students a thorough understanding of the science and technology behind various forming processes.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to Metal Forming:** Introduction; Importance of metal working; Review of mechanisms of plastic deformation; Stress-strain relationships; Yield criteria and their significance; Concept of flow stresses; Metallurgical aspects of metal forming; Hot, warm and cold working processes.	6	The students will be able to differentiate between different working processes.
II	**Fundamental to Metal Forming:** Classification of forming processes; Advantages and Limitations; Mechanics of metal working; Effects of temperature, strain rate, microstructure, friction and lubrication in metal forming; Determination of flow stress for metal working; Workability; Role of hydrostatic pressure; Residual stress;	8	The students will be able to describe the metal forming processes by simple mathematical equations.
III	**Forging:** Introduction and Classification; Operation and principle of Forging Processes and Equipment, Methods of forging, Open and Close Die Forging Processes, Defects, Structure and Properties of Forged Products; Force Analysis in forging.	6	The students will know about different types of forging and the associated forging defects.
IV	**Rolling:** Introduction and Classification; Types of Rolling Mills; Forces and Geometrical Relationships in Rolling, Calculation of Rolling Load, Roll Pass Design, Defects in Rolled Products; Rolling mill control and automation.	6	The students will be able to analyze the rolling process and calculate rolling loads.
V	**Extrusion:** Introduction and Classification; Extrusion Equipment; Forces in extrusion; Analysis of Extrusion Process, Extrusion of components including Seamless Pipes and Tubes; Extrusion of pipes by cold working; Impact Extrusion, Hydrostatic Extrusion; Defects in extruded products.	5	The students will be able to analyze different extrusion processes.
VI	**Drawing:** Introduction and Classification; Wire Drawing, Rod Drawing, Tube Drawing, Deep Drawing, Analysis of Wire Drawing Process and Load Calculations, Tube drawing; Defects and remedies.	5	The students will be able to calculate loads associated with different drawing processes.

VII	**Sheet Metal Forming:** Principle, process parameters, equipment and application of the following processes: shearing, spinning, stretch forming, blanking, bending etc. Explosive forming, Hydro forming, electro hydraulic forming, and magnetic pulse forming. High Velocity forming of metals and High energy Rate forming.	6	The students will be able to describe and analyze different sheet metal forming processes.
	Total	**42**	

Course Outcome	CO1: On completion of this course, the students should be able to describe different metal forming processes and identify defects associated with each process CO2: The students should gain an in-depth knowledge of the mechanics of different metal forming processes, and calculate different processing parameters

Learning Resources	1. Mechanical Metallurgy, G. E. Dieter, McGraw Hill, New Delhi 2. Mechanical Working of Metals-Theory and Practice, PJ.N. Harris, Pergamon Press 3. Metal Forming: Mechanics and Metallurgy, W.F. Hosford and R. M. Caddell, Prentice-Hall 4. Principles Industrial Metalworking Processes, G.W. Rowe, CBS Publishers & Distributors 5. Fundamentals of Metal Forming Processes, B.L. Juneja, New Age Int. Publ

Course Code	MM3171N	Course Name	**Mechanical Testing of Materials Laboratory**	Course Category	**PC**	L	T	P
						0	**0**	**3**

Pre-requisite Courses	*NIL*	Co-requisite Courses	*NIL*	Progressive Courses	*NIL*
Course Offering Department		**Metallurgy and Materials Engineering**		Data Book / Codes/Standards	ASTM Standards

Course Objective	To develop hands-on skills and foundational understanding of mechanical testing methods, and failure analysis, enabling students to interpret material behaviour under various loading conditions and correlate test results with material properties, performance, and relevant industrial standards.

Lab.	**Syllabus**	**Duration (hour)**	**Outcome**
I	Introduction to Mechanical Testing and Standards	3	Understand the purpose, classification, and standardization of mechanical tests (ASTM, ISO). Overview of lab safety and equipment.
II	Rockwell Hardness Test	3	Measure hardness using Rockwell methods; understand the scale selection.
III	Brinell and Vickers Hardness Tests	3	Compare Brinell and Vickers hardness methods.
IV	Nanoindentation and Microhardness Testing	3	Perform micro/nano hardness tests; understand the principles of indentation size effect and Oliver-Pharr method.
V	Tensile Test using different metallic materials	3	Conduct tensile testing, analyze stress-strain curves, and extract properties like yield strength, UTS, strain hardening exponent, and elongation.
VI	Compression Test	3	Perform compression tests on ductile and brittle materials; compare stress-strain behavior.
VII	Torsion Test	3	Measure torsional behavior; determine shear modulus and torsional yield strength.
VIII	Bending Tests	3	Conduct 3- and 4-point bending tests and evaluate flexural strength and modulus; understand bending failure modes.
IX	Impact Test	3	Measure impact toughness by Charpy method; observe ductile-brittle transition behavior.
X	Fatigue Test	3	Understand high- and low-cycle fatigue as well as interpret an S-N curve.
XI	Creep Test	3	Measure creep behavior at elevated temperatures; interpret creep curves and rupture time.
XII	Fractography and Failure Analysis	3	Analyze fracture surfaces under SEM; distinguish ductile, brittle, intergranular, and transgranular failure.
XIII	Non-Destructive Testing Methods	3	Perform and interpret basic NDTs like dye penetrant, ultrasonic, magnetic particle, and eddy current tests.
XIV	Viva	3	Assess theoretical and practical understanding through comprehensive testing and oral examination.
Total		**42**	

Course Outcome	On completion of the course, the students should be able to CO1: Perform standard mechanical tests to evaluate material properties using ASTM/ISO protocols. CO2: Analyse experimental data to interpret material behavior under different loading conditions and correlate with failure mechanisms. CO3: Demonstrate proficiency in using destructive and non-destructive testing techniques to assess material performance, integrity, and suitability for engineering applications.

Learning Resources	Dieter, G.E., ***Mechanical Metallurgy***. 3rd ed., McGraw-Hill, 1986. **Bhargava, A.K., Sharma, C.P. and Singh, L.P., 2012. *Mechanical behaviour and testing of materials***. PHI Learning, 2012 **ASTM International, *Annual Book of ASTM Standards***. West Conshohocken, PA: ASTM International, 2023. **Suryanarayana, A.V.K. *Testing of Metallic Materials***. 2nd ed. New Delhi: Prentice-Hall of India, 2015.

Course Code	MM3172N	Course Name	Joining of Materials Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	
	• To provide hands-on experience in fundamental and advanced material joining techniques. • To develop skills in operating welding equipment and evaluating joint quality. • To analyze process parameters and defect formation in joined structures.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Lab orientation: Safety protocols, equipment familiarization, and material handling	3	Apply safety standards and identify functions of key joining equipment.
II	Manual Metal Arc Welding (MMAW): Electrode selection, technique practice, spatter loss calculation	6	Perform MMAW with minimal spatter and calculate efficiency.
III	TIG/MIG welding: Setup, parameter adjustment, and practice on ferrous/non-ferrous metals	6	Operate TIG/MIG equipment to produce high-quality welds.
IV	Soldering & brazing: Techniques, filler materials, and joint inspection	3	Execute soldering/brazing operations and evaluate joint integrity.
V	Resistance spot welding: Parameter optimization for sheet metal joints	3	Optimize welding parameters for defect-free spot welds.
VI	Friction stirs welding	6	Demonstrate friction stir welding techniques to produce defect-free joints in aluminum alloys by optimizing tool rotation speed, traverse rate, and axial force.
VII	Joint microstructure and strength examination, Identification of HAZ in welded samples.	6	Evaluate joint strength and correlate with joint microstructure

Course Outcome	
	• Technical Proficiency: Safely operate soldering, brazing, and welding equipment per AWS/ASME standards. • Quality Assessment: Identify defects, calculate spatter loss, and evaluate joint integrity. • Process Optimization: Adjust parameters (current, gas flow, speed) for optimal joint quality.

Learning Resources	
	• Joining of Materials and Structures: From Pragmatic Process to Enabling Technology, Robert W. Messler Jr., Butterworth-Heinemann; 1 edition • Welding, D. Greary and Rex Miller, McGraw-Hill Education; 2 edition • Welding: Principles and Applications, Larry F. Jeffus, Thomson Delmar Learning, 5th edtion

Course Code	MM3173N	Course Name	Solidification Processing Lab	Course Category	PSE	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	To introduce mold preparation and experimental techniques used in solidification and casting processes. To provide practical understanding of possible casting defects and possible measures to eliminate those casting defects.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Orientation: Equipment Layout of Foundry Shop; Introduction to Pattern Shop; Demonstration of Job in Foundry Shop	6	The students will be able to identify the layout and key equipment used in a standard foundry shop, including molding, melting, and casting areas.
II	Interpretation of Layout Diagram in Pattern Shop	3	The students will be able to understand the workflow and spatial arrangement required for efficient and safe pattern-making operations.
III	Drawing patterns: Drawing (Orthogonal and isometric) in Pattern Shop	3	The students will be able to interpret technical drawings to understand dimensions, tolerances, and geometrical features relevant to pattern making.
IV	Pattern-making in pattern shop	3	The students will be able to identify different types of patterns (e.g., single-piece, split, match-plate) and select appropriate materials based on application requirements.
V	Methoding in Pattern Shop: Gating System & Calculation; Selection of Parting Line	3	The students will be able to design basic gating systems (sprue, runner, gate) suitable for specific casting requirements.
VI	Mold Preparation: Practical classes for different types of Jobs in Foundry Shop	6	The students will be able to understand and demonstrate the step-by-step procedures involved in mold preparation for various casting jobs
VII	Core-making in Foundry Shop	6	The students will be able to demonstrate the preparation of cores using hand tools and standard core-making techniques.

VIII	Sand Laboratory in Foundry Shop: Universal Strength Measurement (Compression, Shear, Tension); Permeability Test; Moisture Content measurement; Sieve Analysis; Clay Content measurement	6	The students will be able to understand the significance of sand testing in ensuring the quality and consistency of foundry molds and cores.
IX	Melting and pouring of Metal in Foundry Shop	3	The students will be able to demonstrate safe and efficient procedures for melting metals, including temperature control and charge preparation.
X	Identification of defects in castings in Foundry Shop	3	The students will be able to identify and classify common casting defects such as porosity, shrinkage, cold shuts, misruns, and cracks.

Course Outcome	The students will be able to: 1. Demonstrate practical skills in conducting solidification experiments on metals and alloys. 2. Correlate theoretical concepts of solidification with real-world experimental results and casting quality.

Learning Resources	1. Campbell, John. Complete casting handbook: metal casting processes, metallurgy, techniques and design. Butterworth-Heinemann, 2015. 2. Campbell, John. Castings. Elsevier, 2003. 3. Chakrabarti, A. K. Casting technology and cast alloys. PHI Learning Pvt. Ltd., 2022.

Syllabus: Sixth Semester

Course Code	MM3201N	Course Name	Degradation of Materials	Course Category	PC	L	T	P
						3	0	0

Pre-requisite Courses	Engineering Chemistry	Co-requisite Courses	Nil	Progressive Courses	Selection of Engineering Materials
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	ASTM Hand Book

Course Objectives	
	➢ To study the various mechanisms of material degradation and to learn testing methods to evaluate degradation and interpret the results effectively. ➢ Explore prevention and control techniques such as material selection, protective coatings, and environmental management. ➢ Analyze the impact of degradation on material performance and durability in engineering applications.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	An introduction: Technical and economic aspects of the study of surface degradation.	2	Students will understand the technical and economic aspects of surface degradation in materials.
II	Electrochemical principles of corrosion cell; exchange current density; electrode potential and standard cells, EMF series and galvanic series— their applications, application of Faraday's law in corrosion.	5	Students will be able to comprehend electrochemical principles of corrosion, apply Faraday's law to analyse corrosion behaviour.
III	Thermodynamics of corrosion: Pourbaix diagram construction and application, Polarization: types, factors involved, effect on degradation rate; Passivation: factors involved, effect on degradation rate	8	Students will understand corrosion thermodynamics, Pourbaix diagrams, polarisation, and passivation behaviour.
IV	Mixed Potential theory; Tafel equation, construction and interpretation of Polarization diagrams active and active-passive metals and alloys in different environments.	6	Students will know mixed potential theory, the Tafel equation, and polarisation diagram interpretation.
V	Different forms of degradation -uniform attack, galvanic, crevice, pitting, inter-granular, selective leaching, erosion corrosion and stress corrosion cracking, Hydrogen effect, corrosion fatigue and microbes induced corrosion. Liquid metal embrittlement-their characteristic features, causes and remedial measures. Surface degradation testing methods and interpretation of results.	8	Students can identify various forms of surface degradation, understand their mechanisms, characteristics, testing methods, and suggest appropriate remedial measures for material protection.
VI	High temperature surface degradation — Mechanism to formation films on the surface, Pilling-Bedworth ratio, and their effects on kinetics, oxide defect structures, rate laws, types	6	Students will understand high-temperature oxidation mechanisms, film formation, Pilling-Bedworth ratio, oxide defect structures, rate laws, and

	of oxidation, materials for use at elevated temperatures.		material selection for elevated temperatures.
VII	Degradation by wear of materials; its characteristics, wear testing and measurement, Wear-resistant materials	3	Students can assess wear mechanisms, testing methods, and wear-resistant material selection.
VIII	Preventive measurement of surface degradation: material selection and design aspects; control of environment including inhibitors, cathodic and anodic protection, coatings and other surface protection techniques of metals and alloys.	4	Students will understand surface degradation prevention via materials, design, protection, and coatings.

Course Outcome	✔ Students will gain a thorough understanding of the mechanisms and types of material degradation such as corrosion, wear, and high-temperature oxidation. ✔ Student will understand the electrochemical and thermodynamic principles of corrosion and different forms of material degradation. ✔ The course also equips students with knowledge of preventive measures, to enhance material durability and performance in engineering applications.

Learning Resources	1. Corrosion Engineering, 3rd Ed., Mars G. Fontana, McGraw-Hill, Singapore. 2. Corrosion and its Control, 3rd Ed., H.H. Uhlig and R.W. Revie, John Wiley, Singapore. 3. Stress corrosion cracking: Theory and Practice, V S Raja and T Shoji (eds), Woodhaed Publishing Limited, Oxford. 4. Corrosion Failures: Theory, Case Studies and Solutions, K.E. Perumal and V.S. Raja; John Wiley & Sons, USA 5. A.S. Khanna, Introduction to High Temperature Oxidation and Corrosion, ASM International, Materials Park, Ohio

Course Code	MM3221N	Course Name	Alloy Steel & Cast Iron	Course Category	PSE	L	T	P
						3	0	0
Pre-requisite Courses	NIL	Co-requisite Courses		NIL	Progressive Courses	NIL		
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes / Standards			NIL	

Course Objectives	1. To equip students with the knowledge of fundamentals of alloy steel and cast irons, analyses of microstructure and mechanical properties, innovation and newer applications. 2. To produce skilled professionals who can contribute to the advancement of alloy steel, cast iron and their applications in various industries.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction:** Effect of alloying elements on the structure and properties of steel. Solubility and diffusivity of solute atoms in iron-based systems.	06	Introduction to alloying elements on steel
II	**Stainless steels:** Classification and Properties, Austenitic stainless steels, Fe-Cr-Ni system, Chromium carbide in Cr–Ni austenitic steels Intermetallic precipitation in austenite, Austenitic steels in practical applications, Duplex and ferritic stainless steels.	04	Understanding the stainless steel
III	**Low and high alloy steels:** Evolution of microstructures, Effect of multiphase microstructure on the mechanical properties of steel. Tool Steel, High Speed Steel, Dual Phase Steel, HSLA steels, Bainitic steels, IF steels, TRIP steel, TWIP steel, CP steel	10	Understanding the microstructure and mechanical properties of alloy steels
IV	**New generation steels:** Physical metallurgy of new generation steels – ultra low carbon steels, precipitation hardenable steels, steels inheriting transformation induced plasticity, high strength low alloy steels, Ultra high strength steels.	08	Understanding the physical metallurgy of new generation steels
V	**Emerging steels:** Emerging steels for off shore and on shore applications. Theories for improvement of time dependent properties of steels.	04	Understanding the physical metallurgy of emerging steels
VI	**Cast iron:** Nucleation and growth of graphite in cast iron. Types and uses. Alloying of cast iron-its influence on the microstructures, Effect of microstructures on the properties of alloy cast iron. Austempered ductile iron, its processing-structure-property correlation, emerging alloy cast iron of varying morphology of graphite.	10	Understanding the microstructure-property correlation of alloy cast irons

Course Outcome	Students can apply the acquired knowledge on alloy steel and cast iron to design, analyse and develop innovative solutions to complex problems to achieve common goals. The learners will be well-equipped to pursue careers in research, industry, or academia, and make significant contributions to the field of alloy steel and cast iron.

Learning Resources	1. F. B. Pickering: Physical Metallurgy and the Design of Steels, Applied Science Pub. 1978. 2. W. C. Leslie: Physical Metallurgy of Steels, Techbooks Pub. 1991. 3. H.K.D.H. Bhadeshia, R.W.K. Honeycombe: Steels: Structure, Properties, and Design, 5th edition, Butterworth-Heinemann Pub. 2024. 4. Leroy Sidney: Alloy Steel: Properties and Use, Scitus Academics LLC Pub. 2017. 5. H. T. Angus: Cast Iron: Physical and Engineering Properties, 2nd edition, Butterworth-Heinemann Pub. 1976. 6. Roy Elliott: Cast Iron Technology, Butterworth-Heinemann Pub. 1988.

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">MM3222N</td><td rowspan="2">Cours e Name</td><td rowspan="2">Ceramic and Composite Materials</td><td rowspan="2">Course Category</td><td rowspan="2">PSE</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>3</td><td>0</td><td>0</td></tr>
<tr><td>Pre-requisite Courses</td><td>NIL</td><td colspan="2">Co-requisite Courses</td><td>NIL</td><td>Progressive Courses</td><td colspan="3">NIL</td></tr>
<tr><td colspan="2">Course Offering Department</td><td colspan="2">Metallurgy and Materials Engineering</td><td colspan="3">Data Book / Codes / Standards</td><td colspan="2">NIL</td></tr>
</table>

Course Objectives	1. To equip students with the knowledge of fundamentals of ceramic and composite materials, design and analysis, innovation and newer applications, problem-solving and project development. 2. This course aims to produce skilled professionals who can contribute to the advancement of ceramic and composite materials and their applications in various industries.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Ceramic materials** Introduction to ceramics, Common crystal structures in ceramics; silicates, clay, minerals, graphite and carbides, structure of glasses. Imperfections in ceramics, Classification of ceramics and their applications; Ceramic raw materials and their characterisation, Raw material preparation and processing of ceramics, Casting processes like drain casting, tape casting etc. Properties of ceramic powder particle size, shape and surface properties. Flocculation and rheology.	04	Introduction to ceramic materials of materials engineering
II	**Phase transformation and processing** Phase diagrams and phase transformation in ceramic material. Forming Processes: Extrusion, Pressing, Injection Moulding.	04	Understanding phase transformation and forming of ceramic material
III	**Mechanical behaviour** Mechanical behaviour of structural ceramics-brittleness and its improvement, Different toughness measuring techniques. Significance of fracture toughness, elastic modulus and strength of structural ceramics. Electrical, magnetic and optical properties of important ceramic systems.	06	Understanding mechanical behaviour and other important properties of ceramic material
IV	**Functional ceramics** Diverse applications in cutting tools, mobile phone microwave devices polycrystalline diamond and solid oxides for fuel cells, Introduction to electroactive ceramics and bio-ceramics.	06	Understanding diverse applications of ceramic materials
V	**Composite materials** Definition and classification of composite materials. Dispersion strengthened, particle reinforced and fibre reinforced composites, Mechanics and strengthening mechanisms in composite materials. Properties of composites: Elastic Properties, Strength and toughness.	06	Introduction to composite materials of materials engineering
VI	**Design of composites** In-situ and ex-situ composites; Interfaces between reinforcements and matrices in composites; Bonding Mechanisms, Bond Strength, Interfacial Toughness.	06	Understanding the design of composites
VII	**Diversities of composites** Polymer Matrix Composites: Polymer Matrices, Processing Techniques, Glass Reinforced Plastics, Carbon Fibre Composites;	08	Understanding the varieties of composites

	Metal Matrix Composites; Metal Matrices, Processing Techniques, Interfacial Controls, Discontinuously Reinforced Composites, Fibre Composites; Ceramic Matrix Composites: Ceramic Matrices, Processing Techniques, Alumina Matrix Composites, Glass Matrix Composites.		
VIII	**Recent developments** Self-healing (Repairing) composites, Nano-composites, Bio-composites and their usefulness.	02	Understanding the recent developments in composite materials

Course Outcome	1. Upon completing a course in Ceramic and Composite Materials, students are expected to apply knowledge to design, analyse and develop innovative solutions to complex problems to achieve common goals related to ceramic and composite materials. 2. The learners will be well-equipped to pursue careers in research, industry, or academia, and make significant contributions to the field of ceramic and composite materials.

Learning Resources	1. M. Barsoum: Fundamentals of Ceramics, CRC Press, Taylor and Francis Group. 2. W. F. Smith and Javad Hashemi: Foundations of Materials Science and Engineering: McGraw-Hill Publisher 3. F. L. Mathews and R. D. Rawlings: Composite Materials: Engineering and Science, Woodhead Publishing Limited. 4. K. K. Chawla: Composite Materials: Science and Engineering, Springer. 5. T. W. Clyne and D. Hull: An Introduction to Composite Materials, Cambridge University Press.

Course Code	MM3223N	Course Name	Computational Materials Engineering	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	
	1. Development of understanding of computational approach of materials science and engineering. 2. Application of computational approaches for the development of composition-microstructure-property correlation using computational modelling approaches.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Need of Computational Materials Engineering: Examples of challenges in design of materials for challenging applications, bottleneck areas of materials technology, introduction to the Integrated Computational Materials Engineering (ICME) approach.	05	Introduction to the computational approach of materials engineering.
II	Atomistic schemes in Computational Materials Engineering: Introduction to basics of statistical mechanics, basics of molecular dynamics simulation, application of molecular dynamics for property prediction, basics of Monte Carlo approach and its application for modelling materials properties.	12	Understanding of atomistic approach of materials modelling
III	Prediction of thermodynamic properties of materials: Application of CALPHAD type approaches for prediction of phase diagrams and introduction to recent algorithms using atomistic simulations.	06	Application of phenomenological approach of thermodynamic modelling
IV	Mesoscale methods in materials science: Quantification of microstructure: Application of Monte Carlo and Cellular Automata method for generation of microstructure, Introduction to Phase Field Method and Finite Element Method.	07	Understanding of meso-scale materials models.
V	Basics of Multiscale Modelling involving development of method for improved structure-property correlation: Basics of bridging schemes in multiscale models.	05	Understanding of scale-bridging algorithms
VI	Machine Learning in Materials Science: Introduction to Machine Learning, Data Pre-processing, Supervised Learning Algorithms including Artificial Neural Networks, Linear Regression, and Bayesian classification and Hidden Markov Models, Unsupervised	07	Development of understanding of application of artificial intelligence algorithms for materials modelling.

	Learning Algorithms, Optimisation techniques, Evolutionary algorithms.		

Course Outcome	1. Understanding of method of problem formulation for computational modelling of materials phenomena. 2. Application of various computational modelling approaches for studying the structure-property correlations.

Learning Resources	1. Computational Materials Engineering: An Introduction to Microstructure Evolution, KGF Janssens, D. Raabe, E. Kozeschnik, M. Miodownik, B. Nestler, Academic Press. 2. Statistical mechanics: A survival guide, A. M. Glazer and J. S. Wark, Oxford University Press. 3. Integrated Computational Materials Engineering (ICME) for Metals: Using multiscale modelling to invigorate engineering design with science, M.E. Horstemeyer, Wiley. 4. Machine Learning, Anuradha Srinivasaraghavan, Vincy Joseph, Wiley. 5. Deep Learning using Python, S. Lovelyn Rose, L. Ashok Kumar, D. Karthika Renuka, Wiley

Course Code	MM3224N	Course Name	Electronic and Magnetic Materials	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	
	1. Development of understanding of application of Physics of Materials to the evolution of electronic and magnetic properties of materials. 2. Application of basic concepts of materials physics to the electronic devices.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Semiconducting Materials** Fundamentals of band theory and electronic conduction. Intrinsic and extrinsic semiconductors, Compound semiconductors Semiconductor devices: Metals-semiconductor contacts, Diode, solar cell, transistors, quantum semiconductor devices, digital circuits and memory devices and Semiconductor device fabrication.	09	Development of fundamental understanding of semiconductors.
II	**Linear dielectrics** Introduction to dielectric properties of materials. Capacitors: ceramic capacitors, non-ceramic capacitors. Low, medium, and high-permittivity materials	08	Basics of dielectric materials.
III	**Ferroelectric, Piezoelectric, and Pyroelectric materials** Introduction to Ferro, Piezo, and Pyroelectric behaviour of materials, ABO3 structure and ferroelectricity, Piezoelectric behaviour of ferroelectrics, Devices based on piezoelectrics: expander plate. Technologically important piezoelectrics, Lead zirconate titanate, Pyroelectric materials and devices	11	Development of basic property evolution in ionic materials.
IV	**Magnetic Materials** Introduction to magnetism Diamagnetic, Paramagnetic, Superparamagnetic , Antiferromagnetic, and Ferromagnetic materials, Magnetostrction, Magnetocrystalline anisotropy , Spinel ferrites, Hexaferrites, Garnets, Preparation of ferrites Soft and Hard magnetic materials Magnetic data storage materials: Magnetic hard disks, tapes, MRAMs, CDs and DVDs Inductors and transformers for small signal applications, Transformer for power applications, Antennas, Microwave devices	14	Development of basics of magnetism as an electronic phenomenon and its applications.

	Magnetooptics.		

Course Outcome	• Understanding of electronic phenomena and its application for semiconducting, dielectric, ferroelectric, piezoelectric, pyroelectric properties of materials. • Understanding of magnetic properties: fundamentals and applications for engineering materials.

Learning Resources	1. Materials Science and Engineering: A First Course, V. Raghavan, Sixth Edition, PHI. 2. Introduction to Magnetic Materials, B. D. Cullity and C. D. Graham, Wiley

Course Code	MM3271N	Course Name	Degradation of Materials Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	ASTM Handbook

Course Objectives	
	➢ Understand different modes of material degradation such as corrosion, wear, and oxidation. ➢ Perform experiments to evaluate corrosion rates and mechanisms using electrochemical and weight loss methods. ➢ Interpret experimental data to recommend suitable materials and protective measures against degradation.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Corrosion rate measurement by immersion test method in various media (acidic and basic) of (a) Uncoated and coated steel, (b) Non-ferrous metals and alloys	6	Measure corrosion rate of uncoated/coated steel and non-ferrous alloys by immersion in acidic/basic media.
II	Corrosion rate (CR) measurement by current density method (Polarization study) in various acidic and basic medias (a) Different % of carbon in steel (0.3, 0.5, 0.8 and 1.1wt%C) (b) Different stainless steel (Austenitic SS, Martensitic SS and Duplex SS)	6	Measure corrosion rates of carbon and stainless steels using polarization technique in acidic and basic media.
III	CR measurement by current density method (Polarization study) in various acidic and basic medias of Composite (aluminium metal matrix), Ceramic and Polymer material	6	Evaluate corrosion rate of aluminum composites, ceramics, and polymers using polarization in acidic and basic media.
IV	Measure the CR of different velocity of media on Mg alloy and Ti alloy	6	Measure corrosion rate of Mg and Ti alloys under varying media velocities in different environments.
V	Open Circuit Potential, Potentiostatic, Potentiodynamic measurement using inhibitors in acid and basic media for metallic materials	6	Perform OCP, potentiostatic, and potentiodynamic measurements with inhibitors in acidic and basic media on metals.
VI	Oxidation rate measurement at different temperatures of Pure metal and Alloys	3	Measure oxidation rate of metals and alloys at different temperatures.
VII	Salt-spray test of different uncoated and coated steel	3	Evaluate corrosion resistance of uncoated and coated steels using salt-spray test.
VIII	Wear rate measurement by pin and disc method for different steels and ceramics materials	3	Measure wear rate of steels and ceramics using pin-on-disc method.

IX	Viva Voce	3	Assess practical understanding through experimental testing and oral examination.

Course Outcome	➢ Understand various material degradation mechanisms like corrosion, wear, and oxidation. ➢ Perform standard tests to evaluate degradation rates in metals and alloys. ➢ Analyze effects of environmental factors and protective coatings on material durability. ➢ Interpret experimental data to recommend material selection and protection methods.

Learning Resources	Corrosion and its Control, 3rd Ed., H.H. Uhlig and R.W. Revie, John Wiley, Singapore. Stress corrosion cracking: Theory and Practice, V S Raja and T Shoji (eds), Woodhaed Publishing Limited, Oxford. Corrosion Failures: Theory, Case Studies and Solutions, K.E. Perumal and V.S. Raja; John Wiley & Sons, USA A.S. Khanna, Introduction to High Temperature Oxidation and Corrosion, ASM International, Materials Park, Ohio

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">MM3272N</td><td rowspan="2">Course Name</td><td rowspan="2">Alloy Steel & Cast Iron Lab.</td><td rowspan="2">Course Category</td><td rowspan="2">PSE</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>0</td><td>0</td><td>3</td></tr>
<tr><td>Pre-requisite Courses</td><td>NIL</td><td colspan="2">Co-requisite Courses</td><td>NIL</td><td>Progressive Courses</td><td colspan="3">NIL</td></tr>
<tr><td colspan="2">Course Offering Department</td><td colspan="2">Metallurgy and Materials Engineering</td><td colspan="3">Data Book / Codes / Standards</td><td colspan="2">NIL</td></tr>
</table>

Course Objectives	To equip students with the knowledge of alloy steel and cast iron laboratory, analyses of microstructure and mechanical properties. To produce skilled professionals who can contribute to the advancement of alloy steel and cast iron in various industries.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	An introduction to metallographic techniques and safety in specimen preparation.	03	Introduction to metallographic techniques and safety in specimen preparation.
II	Physical metallurgy concepts in interpretation of microstructures.	03	Understanding the Physical metallurgy concepts in the interpretation of microstructures
III	Metallography, microstructures and hardness evaluation of low and high alloy steels such as HSLA, DP, IF, Bainitic, Martensitic, TRIP, TWIP, High-Speed Steels etc.	12	Understanding the Metallography, microstructures and hardness evaluation of low and high-alloy steels
IV	Metallography and microstructures of Stainless Steels and Maraging Steels using light microscopy and scanning electron microscopy.	06	Understanding the metallography and microstructures of Stainless steels and Maraging steels
V	Quantitative image analysis of multiphase microstructures of a few ferrous alloys, TMT rebars etc.	06	Understanding the quantitative image analysis of multiphase microstructures
VI	Microstructure evolution and hardness measurement of low alloy steel treated under various cooling rates.	06	Understanding the variation of microstructure evolution with the cooling rate
VII	Microstructures and hardness evaluation of austenitic manganese steel castings and alloy cast irons.	06	Understanding the microstructure-property correlation of cast steel and alloy cast irons

Course Outcome	Students can apply the acquired knowledge of alloy steel and cast iron laboratory to design, analyse and develop innovative solutions to complex problems to achieve common goals. The learners will be well-equipped to pursue careers in research, industry, or academia, and make significant contributions to the field of alloy steel and cast iron.

Learning Resources	George L. Kehl: The Principles of Metallographic Laboratory Practice, Mcgraw-Hill Book Company Pub., 1949. George F. Vander Voort: Metallography: Principles and Practice, ASM International Pub. 1984. H.K.D.H. Bhadeshia, R.W.K. Honeycombe: Steels: Structure, Properties, and Design, 5th edition, Butterworth-Heinemann Pub. 2024. Roy Elliott: Cast Iron Technology, Butterworth-Heinemann Pub. 1988.

	ASM Handbook, Volume 9: Metallography and Microstructures, ASM International Pub. 2004.

Course Code	MM3273N	Course Name	Ceramic and Composite Materials Lab.	Course Category	PSE	L	T	P
						0	0	3
Pre-requisite Courses	**NIL**	**Co-requisite Courses**		**NIL**	**Progressive Courses**	**NIL**		
Course Offering Department		**Metallurgy and Materials Engineering**		**Data Book / Codes / Standards**		**NIL**		

Course Objectives	➢ To understand the various ceramic and composite materials and their microstructure. ➢ To familiarise students with the processing routes of ceramic and composite materials. ➢ To develop skills in microstructural analysis and mechanical testing of ceramic and composite materials.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Visit to the lab and acquaintance with the equipment	03	To visit the lab and become acquainted with the equipment
II	Preparation of metal matrix composite	03	Understanding the preparation of metal matrix composite
III	Metallographic sample preparation, microstructure analysis and mechanical properties study of different composite materials	18	Understanding the microstructure and mechanical properties of different composite materials
IV	Metallographic sample preparation, microstructure analysis and mechanical properties study of different ceramic materials	12	Understanding metallographic techniques, microstructure and mechanical properties of different ceramic materials
V	Repeat process	03	Understanding the failure and performing the repeat processes
VI	Laboratory Viva-voce	03	To perform viva-voce examination towards the completion of the lab.

Course Outcome	3. Understanding the processing of metal matrix composite. 4. Identification and microstructural analysis of various ceramic and composite materials. 5. Analyse the mechanical properties of various ceramic and composite materials in different conditions.

Learning	1.	M. Barsoum: Fundamentals of Ceramics, CRC Press, Taylor and Francis Group.

Resources	2.	T. W. Clyne and D. Hull: An Introduction to Composite Materials, Cambridge University Press.
	3.	F. L. Mathews and R. D. Rawlings: Composite Materials: Engineering and Science, Woodhead Publishing Limited.
	4.	Nikhilesh Chawla and Krishan K. Chawla: Metal Matrix Composites, 2nd edition, Springer Pub.
	5.	I. M. Low: Ceramic-Matrix Composites: Microstructure, Properties and Applications, CRC Press, Taylor and Francis Group

Syllabus: Seventh Semester

Course Code	MM4121N	Course Name	Stainless Steel Technology	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	1. Development of the industrial relevance of the stainless-steel technology. 2. To abridge the theoretical understanding of Physical and Process Metallurgy to the industrial processing and application of the stainless steels for the various engineering applications.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Overview of Stainless Steel**: a. What is Stainless Steel? b. Alloying elements in Stainless Steel and their functions. c. Impact of alloying elements on properties of Stainless Steel d. Major grades of Stainless Steel e. Cost implications of alloy addition and substitutes	4	Introduction to the Stainless Steel Technology.
II	**Phase transformations in Stainless Steel**: a. Relevance of Nickel equivalent and Chromium equivalent b. Why Fe-C diagram is inadequate for Stainless Steel? c. Role of alloying elements in ferrite and austenite stabilisation d. Role of deformation induced transformation	5	Understanding of application of Physical Metallurgy to the Phase Transformations in Stainless Steels.
III	**Stainless Steel (SS) making and processing**: a. Complete overview covering Electric Arc Furnace, Argon oxygen decarburisation, Ladle Refining, Vacuum Oxygen Decarburisation, Vacuum degassing, Ingot casting vis-à-vis Continuous casting, Hot Rolling, Annealing and Pickling, Cold Rolling, Final Annealing and Pickling, Skin Pass Mill, Strip Grinding Line b. Various Finishes in Stainless Steel c. Colour Coating of Stainless Steel	8	Understanding of the steelmaking and its application for primary processing of stainless steels.
IV	**Stainless Steel fabrication:** a. Cold roll forming (CRF) process mechanism b. Cutting of Stainless Steel c. Welding of Stainless Steel i. Sensitization/Weld decay: Causes, mechanisms, remedies 1. High temperature sensitization 2. 475 C embrittlement 3. α' phase transformation ii. Distortion: Causes, mechanisms, remedies iii. Effect of alloying elements on weldability of SS: 1 Schaeffler De Long diagram interpretations d. Tools and Equipment e. Issues faced during fabrication of stainless steel and their Solutions	4	Understanding of secondary processing and weldability of various stainless-steel grades.

V	**Corrosion in Stainless Steel:** a. Major types of corrosion b. Galvanic corrosion: Mechanism and prevention c. Pitting Corrosion: Mechanism and prevention, Interpretation of PREN d. Crack propagation mechanisms i. Inter-granular and ii. Trans-granular.	5	Understanding of corrosion-resistance and its mechanisms for stainless steels.
VI	**Testing, Handling and Storage of Stainless steel:** a. PMI technique b. Other NDT methods c. Recommended procedures for storage	2	Understanding of testing methods with emphasis to the NDT methods applied to the stainless-steel production.
VII	**Applications of Stainless Steel in various Segments:** a. Automotive, Railways & Transport b. Architecture, Building & Construction c. Reinforcement bars d. Roofing sheets e. Material Handling applications f. Process Industries g. Life Cycle Cost Analysis	6	Relevance of the stainless-steel technology for the various engineering applications.
VIII	**Plant visit for students:** a. Hisar or Jajpur	8	Overview of the engineering challenges and innovations in the fabrication and application of stainless-steel technology.

Course Outcome	1. Appreciation of the innovations in the stainless-steel technology and its application in the various challenging applications. 2. Understanding of the application of theoretical knowledge of Physical and Process Metallurgy for the industrial stainless-steel technology.

Learning Resources	Physical Metallurgy: Principles and Practice, V. Raghavan, Third Edition, 2022, PHI Learning Private Limited, Delhi. STAINLESS STEELS: AN INTRODUCTION TO THEIR METALLURGY AND CORROSION RESISTANCE NO 14056 By Arthur H. Tuthill and Roger A. Vol. 20, July 2000.

Course Code	MM4122N	Course Name	Powder Metallurgy	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	
	• Understand the principles and methods of powder production, characterization, and compaction techniques. • Learn sintering processes, microstructural evolution, and mechanical property development in powder-based components. • Apply powder metallurgy in the design and manufacturing of advanced materials for engineering and industrial applications.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction:** Development, scopes and applications of powder metallurgy	5	Understand the principles, processes, and applications of producing materials and components from metal powders efficiently.
II	**Powder Production processes:** Different metal powder production (mechanical methods and physic-chemical and chemical methods) viz. crushing, grinding, milling, atomization, reduction, electrolysis, carbonyls etc.	6	To understand various methods of producing metal powders and their influence on properties, quality, and applications.
III	**Characterization of metal powders:** chemical compositions, structure, shape, size and their determination, powder flow, apparent density, tap density, compressibility and porosity measurements; powder conditioning and treatments	6	To understand the physical and chemical properties of metal powders for quality control, processing, and application development.
IV	**Compaction**: behavior of metal powders during compaction, Different compaction techniques like die compaction, isostatic pressing, powder rolling, powder extrusion etc. Types of presses, tooling and die design	5	To understand densification mechanisms, optimize pressure application, and improve mechanical properties in powder metallurgy and ceramic processing.
V	**Sintering:** Mechanism of theory of sintering of single component powders, sintering of mixed powders and composites, liquid phase sintering, reactive sintering, activated sintering, sintering furnaces and atmosphere etc	5	To understand particle bonding mechanisms during sintering for optimizing density, strength, and properties of powder-based materials.
VI	**Applications:** production and usage of powder metallurgy products viz. cemented carbides, porous parts, structural parts, dispersion strengthened materials, aerospace applications etc	15	To understand production techniques, material properties, and industrial uses of powder metallurgy for advanced manufacturing applications.

Course Outcome	➢ Understand the principles of powder production, characterization, and compaction techniques used in powder metallurgy processes. ➢ Analyze sintering mechanisms, microstructural evolution, and property enhancement in metal and alloy systems. ➢ Apply powder metallurgy techniques to design and manufacture components for automotive, aerospace, and biomedical applications.

Learning Resources	• R.M. German, Powder Metallurgy Science, 2nd ed. John Wiley, 1999. • A. Upadhyaya, G.S. Upadhyaya, Powder Metallurgy: Science, Technology and Materias, 2011 • ASM Handbook, Volume 7: Powder Metal Technologies & Applications (1998)

Course Code	MM4123N	Course Name	Fracture and Failure Analysis	Course Category	PSE	L	T	P
						3	0	0

Pre-requisite Courses	Mechanical Testing of Materials	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	The primary objective of this course is to provide deeper insight into microstructural mechanisms of how materials/structures fail due to fracture.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to fractography**: Identification of different types of fracture	4	The students will be able to identify microstructural features associated with brittle and ductile fracture.
II	**Linear Elastic Fracture Mechanics**: Estimation of theoretical cohesive strength of brittle materials, Griffith's criterion and equations for plane stress and plane strain, Orowan's and Irwin's equations, Concept of strain energy release rate, Concept of modes of deformation, Concept of stress intensity factor, K_I singularity, plasticity considerations, K_{IC}, CTOD, resistance curves, plane-stress analyses	12	The students will be able to analyze and solve problems associated with brittle fracture.
III	**Interfacial Fracture Mechanics**: theory, crack-path considerations; sub critical crack growth	4	The students will be able to solve problems associated with sub-critical crack growth.
IV	**Nonlinear Elastic Fracture Mechanics**: HRR singularity, J_{IC}, J_R (□a) resistance curves, T_R, CTOA, non-stationary crack-growth analysis.	12	The students will be able to analyze and solve problems associated with ductile fracture.
V	**Environmentally-Assisted Fracture**: stress corrosion, hydrogen embrittlement, corrosion fatigue, Cyclic Fatigue Failure: mechanistic aspects, crack propagation, damage-tolerant analysis, variable amplitude loading small cracks, crack closure, stress-strain/ life analysis	6	The students will be able to analyze and solve problems associated with fatigue and environmentally-assisted fracture.
VI	**Physical Basis of Toughness**: intrinsic toughening - metals, extrinsic toughening - ceramics, composites, Fracture statistics	4	The students will comprehend the microstructural mechanisms of fracture.

Course Outcome	CO1: On completion of this course, the student should be able to identify brittle and ductile fracture from the microstructure. CO2: The student should be able to predict critical crack length for brittle/ductile fracture for different materials, under various conditions, using linear and nonlinear fracture mechanics.

Learning Resources	1. G.E. Dieter: Mechanical metallurgy, McGraw Hill Book Company, New Delhi, 1986. 2. R.W. Hertzberg, R. P. Vinci, and J. L. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, Wiley, 5th edition.

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">MM41244N</td><td rowspan="2">Course Name</td><td rowspan="2">Non-destructive testing</td><td rowspan="2">Course Category</td><td rowspan="2">PSE</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>3</td><td>0</td><td>0</td></tr>
<tr><td>Pre-requisite Courses</td><td>NIL</td><td colspan="2">Co-requisite Courses</td><td>NIL</td><td>Progressive Courses</td><td colspan="3">NIL</td></tr>
<tr><td colspan="2">Course Offering Department</td><td colspan="2">Metallurgy and Materials Engineering</td><td colspan="3">Data Book / Codes / Standards</td><td colspan="2">NIL</td></tr>
</table>

Course Objectives	• To equip students with the knowledge of fundamentals of non-destructive testing, analysis, innovation and newer applications. • To produce skilled professionals who can contribute to the advancement of non-destructive testing and their applications in various industries.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Fundamentals:** Introduction to destructive and non-destructive testing. Scope and limitations of NDT, Defects in casting, forging, heat-treated and other products namely rolled/machined, welded products etc., Causes of defects.	04	Introduction to destructive and non-destructive testing
II	**Visual examination:** Methods. Different visual examination aids.	02	Understanding the visual examination methods and their aids
III	**Leak and pressure testing of industrial components:** Various methods of pressure and leak testing underlying principles of these testing systems.	03	Understanding the methods of leak testing
IV	**Dye penetrant method:** Liquid penetrant testing – procedure; penetrant testing materials, penetrant testing method – sensitivity; application and limitations.	04	Understanding the dye/liquid penetrant methods.
V	**Magnetic particle testing:** Definition and principle; magnetising technique, procedure, equipment, sensitivity and limitations.	04	Understanding magnetic particle testing and its applications
VI	**Ultrasonic methods:** Basic principles of wave propagation, types of waves, methods of UT, their advantages and limitations. Various types of transducers. Calibration methods, use of standard blocks. Inspection methods, the technique for normal beam inspection, flaw characterisation technique, ultrasonic flaw detection equipment, modes of display, Characterisation of defects in castings, forgings, rolled and welded products by UT. Thickness determination by ultrasonic method. Study of A, B and C scan presentations. Immersion testing, advantage, limitations; acoustic emission testing – principles of AET and techniques.	08	Understanding the ultrasonic testing methods and their applications
VII	**Radiographic testing of components:** X-ray and Gamma-ray radiography. Their principles, and methods of generation. Industrial radiography techniques, applications, limitations. Types of films, screens and penetrometers. Interpretation of radiographs. Real-time X-ray radiography. Safety in industrial radiography.	08	Understanding the radiographic examinations and their applications

VIII	**Electrical and thermal methods of NDT:** Conductivity & resistivity methods and their applications. Eddy current testing. Principle, instrument, techniques, sensitivity, application, limitation, Thermal method: principle, equipment, advantages and limitations.	05	Understanding the electrical and thermal methods and their applications
IX	**Selection of NDT Methods:** VI, LPT, MPT, ECT, RT, UT, AET and thermography; reliability in NDT.	04	Understanding the selections of NDT methods

Course Outcome	1. Students can apply the acquired knowledge of NDT methods to design, analyse and develop innovative solutions to complex problems to achieve common goals. 2. The learners will be well-equipped to pursue careers in research, industry, or academia, and make significant contributions to the field of non-destructive testing.

Learning Resources	1. A.V. K. Suryanarayana: Testing of Metallic Materials. PHI Pub. 2. Baldev Raj, T. Jayakumar, M. Thavasimuthu: Practical Non-Destructive Testing. Narosa Pub. House. 3. Ravi Prakash: Non-Destructive Testing Techniques. New Age International Pub. 4. ASM Metals Handbook (Vol. 17): Non-Destructive Evaluation of Materials. American Society of Metals, Metals Park, Ohio, USA. 5. Paul E. Mix: Introduction to Non-destructive Testing: A Training Guide. Wiley Pub.

Course Code	MM4171N	Course Name	Machine Learning in Materials Laboratory	Course Category	PC	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy an Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	
	• To provide knowledge of developing predictive models to forecast materials properties, behavior, and performance using various supervised and unsupervised learning algorithms. • To provide understanding for utilizing software tools and programming languages (e.g., Python, TensorFlow, scikit-learn) to build and validate machine learning models relevant to materials research.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to Materials Data and Machine Learning Tools:** • Introduction to Python and relevant ML libraries (scikit-learn, pandas, matplotlib). • Collect and preprocess materials laboratory data (e.g., composition, microstructure images, property measurements)	6	The Students will demonstrate proficiency in using Python programming language and essential machine learning libraries such as scikit-learn, pandas, and matplotlib for data analysis.
II	**Data Preprocessing and Feature Engineering:** • Handle missing values, normalization, and scaling of materials data. • Extract and engineer meaningful features from raw experimental data (e.g., descriptors from spectra, microstructure images).	6	The Students will be able to perform data transformation and normalization to prepare heterogeneous materials data for machine learning models.
III	**Supervised Learning for Property Prediction:** • Train and evaluate regression models (linear regression, decision trees) to predict materials properties (e.g., hardness, tensile strength). • Performance metrics and model validation techniques (cross-validation, train-test split).	6	The Students will be able to develop and train supervised regression models such as linear regression and decision trees to accurately predict materials properties like hardness and tensile strength
IV	**Classification of Materials Based on Experimental Data:** • Use classification algorithms (SVM, random forest, k-NN) to classify materials	6	The Students will be able to build basic Machine Learning (ML) models and evaluate their performance.

	phases or types based on lab measurements or microstructural images. ■ Confusion matrix and classification accuracy analysis.		
V	**Unsupervised Learning for Materials Characterization**: ■ Apply clustering techniques (k-means, hierarchical clustering) to identify patterns or groupings in experimental materials data. ■ Principal Component Analysis (PCA) for dimensionality reduction and visualization.	6	The Students will be able to apply classification algorithms such to classify materials phases or types using laboratory measurements and microstructural images.
VI	**Predictive Modeling for Materials Design:** ■ Develop machine learning models to predict new materials compositions or process parameters with desired properties. ■ Use model interpretability tools to understand feature importance.	6	The Students will be able to develop machine learning models to predict new materials compositions or process parameters that achieve targeted properties and performance.
VII	**Application of Deep Learning in Materials Engineering :** ■ Build and train fully connected neural networks to predict mechanical or physical properties from input features. ■ Convolutional Neural Networks (CNNs) for Microstructure Image Analysis.	6	The Students will be able to build, train, and evaluate fully connected neural networks (DNNs) Convolutional Neural Networks (CNNs) for Materials engineering sector.

Course Outcome	● The Students will be able to develop and validate predictive models to forecast materials properties and behaviors using regression, classification, and clustering algorithms. ● The Students will be able to preprocess and engineer features from diverse materials datasets, including numerical data and microstructural images, to enhance model performance. ● The Students will be able to implement deep learning methods, such as neural networks and convolutional neural networks, for complex materials data analysis and image-based tasks. ● The Students will be able to evaluate and interpret model outcomes using appropriate performance metrics and visualization tools specific to materials Engineering applications

Learning Resources	1. Butler, Keith T., Felipe Oviedo, and Pieremanuele Canepa. Machine learning in materials science. Vol. 29. American Chemical Society, 2022. 2. Simeone, Osvaldo. Machine learning for engineers. Cambridge university press, 2022.

	3. Krishnan, N. A., Kodamana, H., & Bhattoo, R. (2024). Machine learning for materials discovery: numerical recipes and practical applications. Springer International Publishing AG.

Course Code	MM4172N	Course Name	Stainless Steel Technology Laboratory	Course Category	PSE	L	T	P
						0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		Data Book / Codes/Standards	Nil

Course Objectives	1. To understand the various stainless steels and their microstructure (austenitic, ferritic, martensitic, duplex). 2. To familiarize students with key processes like annealing, quenching, sensitization, and passivation. 3. To develop skills in microstructural analysis, corrosion testing, and mechanical testing of stainless steels.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Microstructure analysis of austenitic stainless steel.	03	Effect of composition on the microstructure of austenitic stainless steels
II	Microstructural analysis of ferritic stainless steel.	03	Effect of composition on the microstructure of ferritic stainless steels
III	Microstructural analysis of martensitic stainless steel.	03	Effect of composition on the microstructure of martensitic stainless steels
IV	Microstructural analysis of duplex stainless steel.	03	Effect of composition on the microstructure of duplex stainless steels
V	Annealing, quenching, tempering of martensitic steels	03	Effect of heat-treatment on the microstructure of martensitic steels
VI	Hardness Testing of heat-treated martensitic steels	03	Effect of microstructure on the mechanical properties of martensitic steels
VII	TIG welding of austenitic stainless steel	06	Effect of welding parameters in joining of austenitic stainless steels
VIII	Microstructural analysis of TIG welded austenitic steel	03	Study of heat-affected zone (HAZ) and sensitization
IX	Corrosion testing of various grades of stainless steel (Salt spray test (ASTM B117) and pitting corrosion test.) with potentiodynamic polarization	09	Development of understanding of corrosion mechanisms in various stainless steels
X	Corrosion testing of various stainless steels in simulated body fluid for biomaterial application	06	Studying the application of stainless steel as a biomaterial

Course Outcome	➢ Identification and microstructural analysis of various stainless-steel grades. ➢ Analyse the mechanical and corrosion-resistance of various stainless-steel grades in different conditions. ➢ Understanding the effect of composition and heat-treatment protocols on the properties of stainless-steels.

Learning Resources	• Physical Metallurgy: Principles and Practice, V. Raghavan, Third Edition, 2022, PHI Learning Private Limited, Delhi • STAINLESS STEELS: AN INTRODUCTION TO THEIR METALLURGY AND CORROSION RESISTANCE NO 14056 By Arthur H. Tuthill and Roger A. Vol. 20, July 2000

Course Code	MM4173N	Course Name	Powder Processing Lab	Course Category	PSE	L	T	P
						3	**0**	**0**

Pre-requisite Courses	Nil	**Co-requisite Courses**	Nil	**Progressive Courses**	Nil
Course Offering Department	Metallurgy and Materials Engineering		**Data Book / Codes/Standards**	Nil	

Course Objectives	▪ Introduce students to fundamental techniques of powder production, characterization, and handling for metallurgical applications. ▪ Develop practical skills in compaction, sintering, and analysis of powder-processed materials. ▪ Enable understanding of the relationship between processing parameters, microstructure, and final material properties through hands-on experiments.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to Powder Processing Lab:** Overview of powder metallurgy process, types of powders and production methods, safety and handling of metal powders	5	Understand the principles, processes, and handling methodology for powders.
II	**Powder Characterization Techniques:** Particle size analysis (sieve, laser diffraction), Morphology examination (microscopy), Flowability and density measurements (tap and bulk density)	6	To analyze powder properties like size, shape, and flow, crucial for quality control and material performance.
III	**Powder Compaction Methods:** Uniaxial pressing, Cold isostatic pressing, Effects of compaction pressure on green density and strength	8	To learn methods of compressing powders into solids, improving material density, strength, and manufacturing quality control.
IV	**Sintering Process:** Principles of sintering, Sintering temperature and time effects, Microstructural changes during sintering	5	To learn powder compaction and heat treatment processes that produce dense, strong materials through sintering.
V	**Testing of Powder Metallurgy Samples:** Mechanical testing (hardness, tensile strength), Density and porosity measurement, Microstructure analysis of sintered parts	5	To evaluate mechanical and physical properties of sintered products, ensuring quality and performance in powder metallurgy.
VI	**Case studies and industrial applications of powder metallurgy:** Cu-Sn, Al-Cu, Cu-TiB2, Al-TiB2 etc.	12	To apply powder metallurgy principles practically, analyze real-world problems, and understand industrial processes and innovations.

Course Outcome	Gain hands-on experience in powder characterization, compaction, and sintering techniques used in powder metallurgy. Develop the ability to analyze the effects of processing parameters on the microstructure and properties of powder-processed materials. Apply laboratory skills to evaluate mechanical and physical properties of powder metallurgy components for industrial applications.

Learning Resources	Handouts

Syllabus: Open Elective from 4th to 8th semester

Course Code	MM2261N	**Course Name**	Selection of Engineering Materials	**Course Category**	OE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	**Co-requisite Courses**	Nil	**Progressive Courses**	Nil
Course Offering Department		Metallurgy and Materials Engineering		**Data Book / Codes/Standards**	Nil

Course Objectives	To develop the ability to identify and select appropriate materials for engineering applications based on mechanical, thermal, electrical, and environmental properties, cost, and sustainability considerations.

Module	**Syllabus**	**Duration (class-hour)**	**Module Outcome**
I	Introduction to metals & alloys, polymers, ceramics and composites, Properties of materials and their evaluations	8	Students will be able to classify and compare different types of engineering materials based on their structure and properties, and evaluate their suitability for various engineering applications.
II	Material property charts: Modulus-Density, Strength-Density, Modulus-Strength, Fracture toughness-Modulus, Thermal conductivity-Resistivity, Wear rate-Hardness,Thermal expansion-Modulus of elasticity.	10	Students will be able to interpret and utilize material property charts to compare and select materials based on performance indices relevant to mechanical, thermal, and functional requirements in engineering design.
III	Material selection strategy, flow of material selection procedure	8	Students will be able to apply systematic material selection strategies and follow structured procedures to identify optimal materials for specific engineering applications, considering

			performance, cost, and environmental factors.
IV	Case studies of material selections: Materials for springs, Elastic hinges, Safe pressure vessels, Damping material for shaker table, Material for solar heating, energy efficient kiln walls, Materials for heat exchangers	8	Students will be able to analyze real-world engineering problems and select appropriate materials by applying material selection principles, performance indices, and case-specific functional requirements.
V	Classification of processes, Shaping, Joining and Machining, Systematic process selection	8	Students will be able to classify manufacturing processes and systematically select appropriate shaping, joining, or machining methods based on material type, design requirements, and production constraints.

Course Outcome	Students will be able to select appropriate engineering materials for specific applications by evaluating mechanical, thermal, chemical, and economic properties in relation to design and performance requirements.

Learning Resources	• Materials Selection in Mechanical Design, Michael F. Ashby • Selection and Use of Engineering Materials Third Edition, 1997, J.A. Charles, F.A.A. Crane and J.A.G. Furness

Course Code	MM3161N	**Course Name**	**Materials for Structural Applications**	**Course Category**	**OE**	**L**	**T**	**P**
						3	**0**	**0**
Pre-requisite Courses	**NIL**	**Co-requisite Courses**		**NIL**	**Progressive Courses**	**NIL**		
Course Offering Department		**Metallurgy and Materials Engineering**		**Data Book / Codes / Standards**			**NIL**	

Course Objectives	1. To equip students with the knowledge of fundamentals of materials for structural application, analyses of microstructure and mechanical properties, innovation and newer applications. 2. To produce skilled professionals who can contribute to the advancement of materials for structural applications in various industries.

Module	**Syllabus**	**Duration (class-hour)**	**Module Outcome**
I	**Introduction:** Definition, Classification, Requirements for structural materials, Overview of engineering applications for automotive, aerospace, civil infrastructure etc.	02	Introduction to structural materials

II	**Structure-Property Relationships:** Crystal structures and phases, Defects and strengthening mechanisms, Microstructure evolution after processing and heat treatment.	04	Understanding the sstructure-property relationships
III	**Ferrous Alloys:** Steels: Classification, phase diagrams, heat treatments (quenching, tempering, Q&P), Stainless steels, Cast irons, Structure-property relationships.	06	Understanding the microstructure and mechanical properties of ferrous alloys
IV	**Non-Ferrous Alloys:** Al, Mg, Ti, and Ni-based alloys: Applications and processing, Lightweight alloys for transportation and aerospace, Alloy design for performance.	06	Understanding the design, processing and application of non-ferrous alloys
V	**Polymers, Ceramics, and Composites:** Structural polymers and fibre-reinforced plastics, Advanced ceramics (alumina, zirconia, SiC) for structural applications, Metal-matrix and polymer-matrix composites.	08	Understanding the significance of non-metallic structural materials
VI	**Testing and Characterisation of Structural Materials:** Mechanical testing (tensile, impact, hardness, fatigue, creep), Non-destructive evaluation (NDE) methods, Microstructural and surface analysis.	06	Understanding the testing and characterisation of structural materials
VII	**Failure of Structural Materials:** Fracture mechanics: Toughness, crack growth, Fatigue and life prediction, Creep deformation and rupture, Environmental effects: Corrosion and stress corrosion cracking.	06	Understanding the failure mechanisms of structural materials
VIII	**Modern Developments and Case Studies:** Advanced high-strength steels (AHSS, Q&P, TRIP, and TWIP), High-entropy alloys, Shape memory alloys, Nanostructured and additive-manufactured structural materials, Real-world failure case studies and forensic analysis.	04	Understanding the modern developments and case studies

Course Outcome	1. Students can apply the acquired knowledge of materials for structural applications to design, analyse and develop innovative solutions to complex problems to achieve common goals. 2. The learners will be well-equipped to pursue careers in research, industry, or academia, and make significant contributions to the field of materials for structural applications.

Learning Resource s	1. W. D. Callister and D. G. Rethwisch: Materials Science and Engineering: An Introduction, 10th edition, Wiley Pub. 2018 2. M. F. Ashby and D. R. H. Jones: Engineering Materials (Volumes 1 & 2), 4th edition, Butterworth-Heinemann Pub. 2012. 3. G. E. Dieter: Mechanical Metallurgy, 3rd edition, McGraw-Hill Education Pub. 2017. 4. T. H. Courtney: Mechanical Behavior of Materials, 2nd edition, McGraw-Hill Education Pub. 2017. 5. Selected journal articles and case studies (provided during the course).

Course Code	MM3261N	Course Name	**Materials for Aerospace Applications**	Course Category	**OE**	L	T	P
						3	**0**	**0**

Pre-requisite Courses	*NIL*	Co-requisite Courses	*NIL*	Progressive Courses	*NIL*
Course Offering Department		**Metallurgy and Materials Engineering**		Data Book / Codes/Standards	ASTM Standards

Course Objective	*To provide a thorough understanding of aerospace materials—including metals, alloys, composites, ceramics, and smart materials—with emphasis on their properties, selection, high-temperature performance, degradation, protection, and application in aerospace design through real-world case studies.*

Module	Syllabus	Duration (hour)	Module Outcome
Module - I	**Introduction to Aerospace Materials** Evolution and classification of aerospace materials; Material requirements for aerospace structures and engines; Weight, strength, creep, corrosion, and fatigue considerations; Materials selection criteria and performance indices (Ashby charts).	**4**	Understand the evolution, classification, and key performance requirements of aerospace materials.
Module -II	**Light Metallic Materials** Characteristics, processing, heat treatment, and properties of Aluminium, Titanium, and Magnesium alloys.	**6**	Explain the characteristics, processing methods, underlying theory, and properties of aluminum, titanium, and magnesium alloys for aerospace applications.
Module -III	**High-Temperature Materials and Superalloys** Nickel-based and cobalt-based superalloys; Strengthening mechanisms (solid solution, precipitation, grain boundary control); Applications in turbine engines and combustion chambers; Oxidation and hot corrosion resistance.	**5**	Understand the properties, strengthening mechanisms, and high-temperature performance of nickel- and cobalt-based superalloys used in aerospace engines, with emphasis on oxidation and corrosion resistance.
Module - IV	**Composite Materials in Aerospace** Polymer, metal, and ceramic matrix composites; Reinforcements: carbon, glass, aramid fibers; Fabrication techniques; Mechanical behavior and failure mechanisms.	**6**	Gain a comprehensive idea regarding the types, fabrication methods, reinforcements, mechanical behavior, and failure mechanisms of composite materials used in aerospace applications.
Module - V	**Ceramics, Refractories and Thermal Barrier Coatings** Advanced ceramics in aerospace: SiC, Al_2O_3, ZrO_2, etc.; Properties and applications in high-temperature environments; Thermal barrier coatings: structure, function, and degradation; Plasma spraying and other deposition techniques.	**5**	Understand the properties, applications, and degradation of advanced ceramics and thermal barrier coatings in aerospace and gain insight into deposition techniques like plasma spraying.
Module - VI	**Smart and Emerging Materials** Shape memory alloys, piezoelectric materials, and magnetostrictive materials; Applications in actuators, morphing structures, and vibration control; Recent	**6**	Gain knowledge of smart and emerging materials—such as shape memory alloys, piezoelectrics, and nanomaterials—and their applications in aerospace actuation,

	developments in ultra-lightweight materials, nanomaterials, and metamaterials		morphing structures, and vibration control.
Module - VII	**Degradation, Damage, and Protection of Aerospace Materials** Corrosion, oxidation, and fatigue mechanisms; High-cycle and low-cycle fatigue in aerospace structures; Non-destructive evaluation and structural health monitoring; Surface treatments and protective coatings.	**6**	Understand degradation mechanisms in aerospace materials and apply protective strategies, non-destructive evaluation, and structural health monitoring techniques.
Module - VIII	**Case Studies and Materials Selection** Material selection for airframes, engines, landing gear, and control surfaces; Case studies: Boeing 787 Dreamliner, Airbus A350, SpaceX, and ISRO missions; Cost-performance trade-offs, sustainability, and recyclability in aerospace design.	**4**	Analyze material selection in aerospace components through case studies, considering performance, cost, sustainability, and recyclability.
Total		**42**	

Course Outcome	On completion of the course, the students should be able to ***CO1***: *Understand and classify aerospace materials based on their properties, performance, and application requirements.* ***CO2***: *Analyze the behavior of metals, composites, ceramics, and smart materials under aerospace operating conditions.* ***CO3***: *Apply materials selection principles to real-world aerospace components considering performance, cost, and sustainability.*

Learning Resources	Mouritz, A.P., 2012. ***Introduction to aerospace materials***. Elsevier. **Baker, A., Dutton, S. and Kelly, D., 2004. *Composite Materials for Aircraft Structures***. 2nd ed. Reston, VA: AIAA Education Series. Ashby, M.F., Shercliff, H. and Cebon, D., 2018. ***Materials: engineering, science, processing and design***. Butterworth-Heinemann. Callister Jr, W.D. and Rethwisch, D.G., 2020. ***Materials science and engineering: an introduction***. John Wiley & Sons. Prasad, N.E. and Wanhill, R.J. eds., 2017. ***Aerospace materials and material technologies*** (Vol. 1). Singapore: Springer. Reed, R.C., 2008. ***The superalloys: fundamentals and applications***. Cambridge University Press. Lin, J., 2022. ***Durability and damage tolerance analysis methods for lightweight aircraft structures: Review and prospects***. International Journal of Lightweight Materials and Manufacture, 5(2), pp.224-250. Gdoutos, E.E. and Konsta-Gdoutos, M.S., ***Mechanical Testing of Materials***. Springer Nature Switzerland, 2024.

Course Code	MM3262N	**Course Name**	**Functional Materials**	**Course Category**	**OE**	L	T	P
						3	0	0

Pre-requisite Courses	Physics of Materials	**Co-requisite Courses**	Thermo-dynamics	**Progressive Courses**	Nil

Course Offering Department	Metallurgy and Materials Engineering	Data Book / Codes/Standards	Nil

Course Objectives	• To provide an understanding of various materials that exhibit specific functionalities stimulated by physical or chemical changes in the surroundings. • To provide an understanding of synthesis, structure, properties, and applications of functional materials. • To make the students learn to apply their knowledge to select design and develop functional materials.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	Overview of functional Materials, structure properties and their classification.	02	The students will be able to differentiate between functional materials and other traditional materials used for known applications.
II	Ferroelectric, Piezoelectric and Piezoelectric Materials: Perovskite structure and spontaneous polarization, relationship of ferroelectrics and piezoelectric to crystal symmetry, Devices based on piezoelectric property, Piezoelectric composites, pyroelectric materials and devices	08	The students will develop an understanding about the functionalities of this class of materials from the viewpoint of their crystal structure and will be able to relate the practicality of this class of materials in several advanced technologies.
III	Shape Memory materials and alloys: Structural Thermo-elastic Phase Transition in Shape Memory Alloys, Dependency Between Microstructure and Elastic Behavior of SMA, Discontinuous Change of Physical Properties— Martensitic Phase Transition, Different Approaches to Describe the Shape-Memory Effect, and Quantitative Models for Shape Memory Alloys	08	The students will understand what are shape memory materials and alloys. What is shape memory effect and how it works in various applications and devices.
IV	Magnetorheological and Electrorheological Fluids: Viscoelastic Properties and Basic Rheology, Some Rheological Models, Understanding the Microscopic Structure of ERF and MRF, ER- and MR-effect Explained by the Interaction of Induced Dipoles, Applications—Switchable Fluid Acting as a Valve	08	The concepts and applicatin of Magnetorheological and electrorheological fluids regarded as smart fluids will be introduced with respect to their applications in dampers, clutches, and other control systems.
V	Nanostructured functional materials: Semiconducting oxide films, Metallic nanoparticles, Carbon-based nanostructured materials for energy storage and conversion	08	The students will learn the basic concepts of nanostructured materials and the effect of nano dimensionality with respect to the changes in the functional properties of the materials.
VI	Functionally graded materials and their applications.	06	This module will equip students with the knowledge and skills to understand, the concepts design, and

			characterize these materials and its applications in different engineering fields. They would also be able to model FGMs, fabricate them using additive or mass transfer processes.
	Total contact hours	**40**	

Course Outcome	After the completion of the course the students will be able will be able to apply their knowledge to solve problems related to functional materials, including designing, synthesis and characterization of functional materials for devices. Students will also develop critical thinking skills to evaluate and understand the scientific literature related to nanomaterials.

Learning Resources	1. Functional Materials: Properties, Performance and Evaluation, Ewa Ktodzinska, CRC Press 2. Functional and smart materials, Chander Prakash, Sunpreet Singh J Paulo Davim, CRC Press. 3. Functional Materials: Preparation, Processing and Applications, S. Banerjee, A. K. Tyagi. Elsevier. 4. The Physics of Multifunctional Materials Concepts, Materials, Applications, Martin Gurka, Destech Pubns Inc 5. Nanostructure Multifunctional Materials by Esteban A. Franceschini, CRC Press

Course Code	MM4161N	**Course Name**	Machine Learning in Materials	**Course Category**	**OE**	L	T	P
						3	**0**	**0**

Pre-requisite Courses	Nil	**Co-requisite Courses**	Nil	**Progressive Courses**	Nil
Course Offering Department		Metallurgy an Materials Engineering		**Data Book / Codes/Standards**	Nil

Course Objectives	• To provide understanding of the foundational principles of machine learning relevant to materials science. • To provide knowledge of application of Machine Learning techniques to solve materials discovery, design, and property prediction problems.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to Materials Informatics:** The motivation and Challenges in materials discovery, History and impact of data-driven methods in materials science.	5	The Students will understand the role and impact of Machine Learning (ML) in materials science.
II	**Materials Data Landscape Types of data:** experimental, simulation, high-throughput,	5	The Students will be able to acquire and preprocess data from materials databases.

	Sources of data (Materials Project, OQMD, AFLOW, Citrine), Data cleaning and preprocessing.		
III	**Mathematics for Machine Learning:** Linear Algebra, Calculus and Gradient-Based Learning, Probability Theory, Statistics and Data Distributions	5	The Students will be able to analyze the mathematical behavior of common Machine Learning (ML) models
IV	**Fundamentals of Machine Learning:** Supervised vs. Unsupervised Learning, Regression and Classification algorithms (Linear regression, SVM, Random Forest, etc.), Model evaluation: accuracy, MAE, R^2, cross-validation.	5	The Students will be able to build basic Machine Learning (ML) models and evaluate their performance.
V	**Feature Engineering in Materials** : Domain-specific features (compositional, structural), Matminer, Pymatgen, feature selection	5	The Students will be able to generate and optimize features for materials Machine Learning (ML) models
VI	**Uncertainty, Interpretability & Model Trust:** Uncertainty quantification (Bayesian ML, ensemble learning), Model interpretability, Physical consistency and interpretability	5	The Students will be able to interpret and evaluate trust in Machine Learning (ML) predictions.
VII	**Applications in Materials Discovery and Design:** Property prediction (bandgap, thermal conductivity, elasticity), Materials screening and inverse design, ML for catalysis and battery materials, Surrogate models for simulations	6	The Students will be able to use Machine Learning (ML) for materials discovery and inverse design workflows.
VIII	**Deep Learning in Materials Engineering :** Convolutional Neural Networks for Materials Imaging, Generative Deep Learning for Materials Design, Transfer Learning, Interpretability, and Physics-Informed Deep Learning	6	The Students will be able to understand core deep learning principles and architectures relevant to Materials engineering problems

Course Outcome	✔ The Students will be able to explain the principles of machine learning and their relevance to materials science and engineering applications. ✔ The Students will be able to collect, preprocess, and manage materials datasets from computational and experimental sources for ML applications. ✔ The Students will be able to develop and implement machine learning models (e.g., regression, classification, clustering) to predict material properties or behaviors. ✔ The Students will be able to design an end-to-end machine learning workflow to solve a real-world materials problem, integrating data handling, modeling, and interpretation.

Learning Resources	1. Liu, Yue, Tianlu Zhao, Wangwei Ju, and Siqi Shi. "Materials discovery and design using machine learning." Journal of Materiomics 3, no. 3 (2017): 159-177. 2. Butler, Keith T., Felipe Oviedo, and Pieremanuele Canepa. Machine learning in materials science. Vol. 29. American Chemical Society, 2022. 3. Simeone, Osvaldo. Machine learning for engineers. Cambridge university press, 2022.

Course Code	MM4261N	Course Name	Biomaterials	Course Category	OE	L	T	P
						3	0	0

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department		Metallurgy and Materials Engineering		**Data Book / Codes/Standards**	Nil

Course Objectives	• To introduce students to the fundamental principles of biomaterials, including their properties, interactions with biological systems, and applications in medical devices. • To develop an understanding of the design, selection, and evaluation of biomaterials for specific biomedical applications. • To explore the challenges and advancements in biomaterials science, including biocompatibility and tissue engineering.

Module	Syllabus	Duration (class-hour)	Module Outcome
I	**Introduction to Biomaterials** Definition, history, and classification of biomaterials (metals, ceramics, polymers, composites). Overview of applications in medical devices and implants.	4	Understand the scope, classification, and historical development of biomaterials used in biomedical applications. .
II	**Structure and Properties of Biomaterials**, Atomic and molecular structure, mechanical properties (strength, elasticity, fatigue), surface properties, and degradation mechanisms.	6	Analyze the structural and mechanical properties of biomaterials and their impact on performance.
III	**Biocompatibility and Host Response** Concepts of biocompatibility, host-tissue interactions, immune response, and toxicity. Testing methods for biocompatibility.	6	Evaluate the biological interactions of biomaterials and methods to assess biocompatibility.
IV	**Metallic Biomaterials**, Properties and applications of stainless steel, titanium alloys,	5	Understand the use of metallic biomaterials in medical

	cobalt-chromium alloys, and shape-memory alloys in implants and devices.		applications and their advantages/limitations.
V	**Ceramic and Polymeric Biomaterials** Bioinert and bioactive ceramics (alumina, zirconia, hydroxyapatite). Natural and synthetic polymers (collagen, PLA, PGA).	5	Analyze the properties and applications of ceramic and polymeric biomaterials in biomedical engineering.
VI	**Composite and Natural Biomaterials** Composite biomaterials design, natural biomaterials (collagen, chitosan), and their applications in tissue engineering	5	Explore the design and application of composite and natural biomaterials in regenerative medicine.
VII	**Biomaterials in Tissue Engineering and Regenerative Medicine** Scaffolds, hydrogels, and 3D bioprinting. Stem cell interactions and tissue regeneration strategies.	5	Understand the role of biomaterials in tissue engineering and their application in regenerative therapies
VIII	**Emerging Trends and Regulatory Aspects** Nanobiomaterials, smart biomaterials, drug delivery systems. Regulatory standards and ethical considerations	5	Evaluate emerging trends in biomaterials and understand regulatory and ethical issues in their development.

Course Outcome	● Students will be able to identify and classify biomaterials, analyze their properties, and select appropriate materials for specific biomedical applications. ● Students will demonstrate an understanding of biocompatibility, host responses, and the role of biomaterials in tissue engineering and regenerative medicine. ● Students will be equipped to evaluate emerging trends and regulatory considerations in the design and application of biomaterials.

Learning Resources	● Ratner, B. D., Hoffman, A. S., Schoen, F. J., & Lemons, J. E. (2013). Biomaterials Science: An Introduction to Materials in Medicine (3rd ed.). Academic Press. ● Park, J., & Lakes, R. S. (2007). Biomaterials: An Introduction (3rd ed.). Springer. ● Temenoff, J. S., & Mikos, A. G. (2008). Biomaterials: The Intersection of Biology and Materials Science. Pearson Prentice Hall. ● Hollinger, J. O. (2011). An Introduction to Biomaterials (2nd ed.). CRC Press.