25MEMJ204 : Material Science and Metallurgy

w. e. f. Academic Year:	2025-26
Semester:	3rd
Category of the Course:	Core Course
Prerequisite:	Basic Science (Physics and Chemistry)
Rationale:	The study of material science and metallurgy is fundamental for mechanical engineers to understand the relationship between the structure, properties, and processing of materials. This course enables students to select appropriate materials for specific engineering applications, predict material behavior under different conditions, and understand the processes that modify material properties to meet industrial requirements

Course Outcomes:

After Completion of the Course, Student will able to:

	Course Outcome (CO)	RBT Level (Cognitive Domain)	Marks % Weightage (approx.)
CO1	Identify and classify engineering materials and their alloys based on atomic structure, mechanical properties, and specific engineering requirements.	Remember	15
CO2	Analyze and interpret Phase Diagrams, specifically the Iron-Carbon system, to understand the solidification and crystallization behaviour of alloys.	Analyze	20
CO3	Distinguish between various grades of Cast Iron and Steel, evaluating the effects of alloying elements on their properties and industrial applications.	Understand	12
CO4	Select and justify appropriate heat treatment processes and powder metallurgy techniques to enhance the mechanical performance of engineering components.	Evaluate	30
CO5	Determine corrosion behavior and apply suitable NDT methods to ensure material integrity with a focus on sustainability and efficient resource utilization.	Apply	23

Teaching and Evaluation Scheme:

Teaching Scheme					Examination Scheme				
L	**T**	**P**	**C**	**Hrs/Week**	**IE**	**EE**	**CIA**	**Practical/ Viva**	**Total Marks**
3	0	2	4	5	40	60	30	20	150

IE: Internal Exam
EE: External Exam (End Semester)
CIA: Continuous Internal Assessment
Practical: Practical Exam (End Semester)

Detailed Syllabus:

Topic		Hrs.	% of Weightage
UNIT: 1	**Atomic structure and Mechanical properties:**	7	15
Introduction to Material Science and Metallurgy: Classification of Engineering Materials, Engineering requirements of materials, Properties of engineering materials, Criteria for selection of materials considering environmental impact and lifecycle sustainability. Metallic Materials: Types, properties and applications, Structure of Metals, Fracture. Non-ferrous alloys: alloys of copper, aluminium, magnesium titanium. Other alloys of lead, tin, zinc, nickel, manganese, white metals and bearing alloys and sustainable applications.			
UNIT: 2	**Phase Diagrams:**	9	20
Iron-Carbon diagram, plain carbon steels, Allotropy of iron. Crystallization of metals, Solidification of an alloy, solid solution types. Thermal Equilibrium diagrams of binary alloys. Effect of structure on properties with consideration of sustainable material performance and durability.			
UNIT: 3	**Iron, Steel and their alloys:**	6	12
Cast Iron, Grades, Alloy cast iron, Malleable Iron, S.G iron, Wrought Iron: Properties and uses. Steel: classification of steel, Properties and uses, Effect of alloying elements with focus on enhancing material life and reducing environmental impact.			
UNIT: 4	**Heat Treatment:**	9	20
Heat Treatment of Steels: Study of Heat-Treatment processes such as Normalizing, Annealing, spheroidizing, hardening, tempering, austempering, martempering, case-hardening, nitriding, cyaniding, induction hardening, flame-hardening, ageing. Applications in mechanical components (gears, bearings, turbine blades, etc.) with emphasis on improving energy efficiency, extending component life, and reducing material waste for sustainable engineering practices.			
UNIT: 5	**Powder Metallurgy:**	4	10
Powder Metallurgy: Application and advantages, Powder production, compacting, sintering, equipment, and process capability emphasizing eco-friendly and resource-efficient processes.			
UNIT: 6	**Corrosion of Metals:**	4	10
Corrosion of metals: meaning, causes and nature. Measures of counteracting corrosion, Metal coatings, Organic coatings, Lining and cladding, Use of Corrosion inhibitors, Cathodic protection against corrosion.			
UNIT: 7	**Metallic Testing:**	6	13
Macro-examination, Spark Test, Sculptures Print, Macro-etching, microscopic examinations, Magnetic Testing, Chemical analysis of			

steel and iron for Carbon, Sulphur & Phosphorous. Non-destructive testing such as Radiography Testing, Dye Penetration Testing, Magnetic Particle Testing, Ultrasonic Testing, and Jominy end quench test.		
	45	**100**

List of Practical:

	Hrs
Study of Metallurgical Microscope.	2
Preparation of specimen for microstructural examination (Grinding, Polishing, Etching).	8
Microstructural observation of Ferrous and Non-Ferrous metals.	2
Standard Hardness tests: Rockwell and Brinell.	2
Study of Heat Treatment furnace and quenching media.	8
Spark Testing for carbon amount identification.	2
Dye Penetrant Testing (DPT)	2
Jominy End-Quench Test (Hardenability)	4
	30

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks in Percentage					
Remember	Understand	Apply	Analyze	Evaluate	Create
15	25	25	20	10	5

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may very slightly from above table.

Reference Books:

1. **Callister, W. D.,** "Materials Science and Engineering: An Introduction," Wiley.
2. **Raghavan, V.,** "Material Science and Engineering," PHI Learning.
3. **Reed-Hill, R. E.,** "Physical Metallurgy Principles," Cengage Learning.
4. **Khanna, O. P.,** "A Text Book of Material Science and Metallurgy," Dhanpat Rai **Publications.**

Teaching Learning Method

- Interactive class room teaching (Microstructure charts).
- Demonstration of samples in the Metallurgy Laboratory.
- Industrial visits to heat treatment shops.
- Online NPTEL/SWAYAM video lectures on Phase Diagrams.

Course Outcomes Mapping:

CO	Course Outcome (CO)	POs/ PSOs Mapped	Cognitive Level (RBT)	Knowledge Category	Class Session (Lecture)
CO1	Identify and classify engineering materials and their alloys based on atomic structure, mechanical properties, and specific engineering requirements.	PO1, PO2, PO3, PO11, PSO1, PSO2	Remember	Conceptual	07
CO2	Analyze and interpret Phase Diagrams, specifically the Iron-Carbon system, to understand the solidification and crystallization behaviour of alloys.	PO1, PO2, PO3, PO4, PO5, PO11, PSO1, PSO2	Analyze	Conceptual & Procedural	11
CO3	Distinguish between various grades of Cast Iron and Steel, evaluating the effects of alloying elements on their properties and industrial applications.	PO1, PO2, PO3, PO4, PO5, PO10, PO11, PSO1, PSO2	Understand	Conceptual	08
CO4	Select and justify appropriate heat treatment processes and powder metallurgy techniques to enhance the mechanical performance of engineering components.	PO1, PO2, PO3, PO4, PO5, PO10, PO11, PSO1, PSO2	Evaluate	Procedural & Metacognitive	10
CO5	Determine the nature of corrosion and apply suitable destructive and non-destructive testing (NDT) methods to ensure material integrity.	PO1, PO2, PO3, PO4, PO5, PO6, PO8, PO9, P10, PO11, PSO1, PSO2	Apply	Procedural	09

Mapping of COs with POs & PSOs:

CO	PO											PSO	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	1	-	-	-	-	-	-	-	1	3	1
CO2	3	3	1	2	2	-	-	-	-	1	1	3	2
CO3	3	2	3	2	2	-	-	-	-	-	1	3	2
CO4	3	2	3	2	2	-	-	-	-	-	1	3	2
CO5	3	3	3	2	3	1	-	1	1	1	1	3	3

3: High, 2: Medium, 1: Low

Sustainable Development Goals (SDG) Integration

This course integrates sustainable engineering principles by emphasizing efficient material selection, energy-efficient processing, durability enhancement, and responsible resource utilization. The course contributes to global sustainability initiatives by aligning with key Sustainable Development Goals (SDGs), promoting environmentally responsible engineering practices and long-term system reliability.

SDG Mapping with Course Outcomes

CO	Course Outcome	Relevant SDGs	Justification
CO1	Identify and classify engineering materials and their alloys based on atomic structure, mechanical properties, and specific engineering requirements.	SDG 4	Builds strong engineering fundamentals and supports informed, sustainable material selection.
CO2	Analyze and interpret Phase Diagrams, specifically the Iron-Carbon system, to understand the solidification and crystallization behaviour of alloys.	SDG 9	Enhances efficient material processing and promotes innovation in industrial applications.
CO3	Distinguish between various grades of Cast Iron and Steel, evaluating the effects of alloying elements on their properties and industrial applications.	SDG 9, SDG 12	Encourages optimal material usage, improved performance, and responsible resource consumption.
CO4	Select and justify appropriate heat treatment processes and powder metallurgy techniques to enhance the mechanical performance of engineering components.	SDG 12	Improves material lifecycle, reduces waste, and supports energy-efficient manufacturing processes.
CO5	Determine the nature of corrosion and apply suitable destructive and non-destructive testing (NDT) methods to ensure material integrity.	SDG 9, SDG 11, SDG 12	Promotes durability, reduces material degradation, and supports sustainable infrastructure and resource efficiency.