ODISHA UNIVERSITY OF TECHNOLOGY AND RESEARCH
Techno Campus, Mahalaxmi Vihar, Ghatikia, Bhubaneswar-751029.

School of Mechanical Sciences

CURRICULUM AND SYLLABI (2024-25)

B. Tech. Metallurgical and Materials Engineering

School of Mechanical Sciences
Programme: Metallurgical and Materials Engineering
FOR BACHELOR OF TECHNOLOGY
COURSES TO BE EFFECTIVE FROM ACADEMIC SESSION 2024– 2025
ADMITTED BATCH
(3rd Semester to 8th Semester)

Abbreviation used:

AC	Audit course	LC	Laboratory Course	PA	Practical Assessment
PC	Professional Core	PR	Project/ Practical/ Internship	L	Lecture
PE	Professional Elective	SE	Seminar/ Expert Lecture/ Etc.	T	Tutorial
OE	Open Elective	IA*	Internal Assessment	P	Practical
MC/BS/HS	Mandatory/ Common Course	EA	End-Semester Assessment		
ACC	Advanced Competency Course				
*Internal Assessment Mark (40 marks) consists of (i) Mid Semester (20 marks), (ii) Quiz/ Assignment/Attendance (20 marks)					

SECOND YEAR (*THIRD SEMESTER*)

Sl. No.	Subject Type	Subject Code	Subject (Theory)	Teaching Hours			Credit
				L	T	P	
1	BS	BH2459	Mathematics – III	3	0	0	3
2	PC	MS2145	Material Science and Engineering	3	0	0	3
3	PC	MS2143	Metallurgical Thermodynamics and Kinetics	3	0	0	3
4	PC	MS2141	Mechanics of Materials	3	0	0	3
5	ACC	MS2147	Smart Factory System (Advanced Competency Course -1)	3	0	0	2
6	HS	BH2439/ BH2437	Engineering Economics / Organizational Behaviour	3	0	0	2
			Subject (Sessional)				
7	LC	MS2541	Mechanical Testing Laboratory	0	0	3	1.5
8	LC	MS2543	Metallography Laboratory	0	0	3	1.5
9	LC	MS2545	Materials Chemistry Laboratory	0	0	3	1.5
10	ACC	MS2547	Smart Factory Laboratory (Advanced Competency Course -1 Lab)	0	0	3	1.5
			Total	**18**	**0**	**12**	**22**

SECOND YEAR (*FOURTH SEMESTER*)

Sl. No.	Subject Type	Subject Code	Subject (Theory)	Teaching Hours			Credit
				L	T	P	
1	PC	MS2142	Non-Ferrous Metal Extraction	3	0	0	3
2	PC	MS2144	Iron and Steel Making	3	0	0	3
3	PC	MS2146	Transport Phenomena	3	0	0	3
4	PC	MS2148	Materials Processing	3	0	0	3
5	ACC	MS2125	Digital Manufacturing and Industry 4.0 (Advanced Competency Course -2)	3	0	0	2
6	HS	BH2437/ BH2439	Organizational Behaviour / Engineering Economics	3	0	0	2
			Subject (Sessional)				
7	LC	MS2542	Mineral Dressing Laboratory	0	0	3	1.5
8	LC	MS2544	Process Metallurgy Laboratory	0	0	3	1.5
9	LC	MS2546	Materials Processing Laboratory	0	0	3	1.5
10	ACC	MS2548	Advanced Digital Manufacturing Laboratory (Advanced Competency Course -2 Lab)	0	0	3	1.5
11	Summer Internship and Research Experience (SIRE - I) *						
			Total	**18**	**0**	**12**	**22**

***Minimum 4 weeks of Summer Course / Training / Internship / Skill Course / etc. after 4th Semester**

THIRD YEAR (*FIFTH SEMESTER*)

Sl. No.	Subject Type	Subject Code	Subject (Theory)	Teaching Hours			Credit
				L	T	P	
1	PC	MS3141	Phase Transformation and Heat Treatment	3	0	0	3
2	PC	MS3143	Deformation Behaviour of Materials	3	0	0	3
3	PC	MS3145	Characterization of Materials	3	0	0	3
4	PE-I	MS3141 MS3143 MS3145 MS3147	1. Additive Manufacturing 2. Physics of Materials 3. Ceramics 4. Surface Engineering	3	0	0	3
5	HS	BH3401/ BH3103	Business Management / Entrepreneurship Development	3	0	0	2
6	MC	IP3401 / IP3403	Environmental Engineering / Industrial Safety Engineering	3	0	0	2
			Subject (Sessional)				
7	LC	MS3541	Heat Treatment Laboratory	0	0	3	1.5
8	LC	MS3543	Computational Laboratory	0	0	3	1.5
9	LC	MS3545	Materials Characterization Laboratory	0	0	3	1.5
10	PSI	MS3741	Seminar on SIRE - I	0	0	3	1.5

Total	**18**	**0**	**12**	**22**

***Project / Seminar / Internship**

THIRD YEAR (*SIXTH SEMESTER*)

Sl. No.	Subject Type	Subject Code	Subject (Theory)	Teaching Hours			Credi
				L	T	P	
1	PC	MS3142	Composite Materials	3	0	0	3
2	PC	MS3144	Corrosion and Degradation of Materials	3	0	0	3
3	PE-II	MS3242 MS3244 MS3246 MS3248	1. Finite Element Modelling of Materials 2. Modelling of Materials Processes 3. Molecular Modelling of Materials 4. Computational Materials Engineering	3	0	0	3
4	PE-III	MS3250 MS3252 MS3254 MS3256	1. Alternative Routes of Iron Making 2. Secondary Steel Making 3. Powder Metallurgy 4. Deformation Processing and Forming	3	0	0	3
5	HS	BH3403/ BH3401	Entrepreneurship Development / Business Management	3	0	0	2
6	MC	IP3403/ IP3401	Industrial Safety Engineering / Environmental Engineering	3	0	0	2
			Subject (Sessional)				
7	PSI	MS3642	Project for Product Development – I / Projects	0	0	6	3
8	LC	MS3542	Composite Materials Laboratory	0	0	3	1.5
9	LC	MS3544	Corrosion Laboratory	0	0	3	1.5
10	Summer Internship and Research Experience (SIRE - II) *						
			Total	**18**	**0**	**12**	**22**

***Minimum 4 weeks of Summer Course / Training / Internship / Skill Course / etc. after 6th Semester**

FOURTH YEAR (*SEVENTH SEMESTER*)

Sl. No.	Subject Type	Subject Code	Subject (Theory)	Teaching Hours			Credit
				L	T	P	
1	PE-IV	MS4241 MS4243 MS4245 MS4247	1. Fuels and Refractories 2. Creep, Fatigue and Fracture 3. Non-Destructive Testing Methods 4. Joining of Metals	3	0	0	3
2	PE-V	MS4249 MS4251 MS4253 MS4255	1. Nanomaterials 2. Biomaterials 3. Energy Materials 4. History and Evolution of Materials	3	0	0	3
3	OE	MS4341 MS4343	Open Elective – I 1. History and Evolution of Materials 2. Ironmaking and Steelmaking	3	0	0	3
4	ACC	MS4141	Mechatronics and IoT (Advanced Competency Course -3)	3	0	0	2
			Subject (Sessional)				
5	PSI	MS4741	Seminar on SIRE - II	0	0	6	1
6	PSI	MS4641/ MS4642	Project for Product Development – II / Internship Project - I	0	0	6	3
			Total	**12**	**0**	**12**	**15**

***Project / Seminar / Internship**

FOURTH YEAR (*EIGHTH SEMESTER*)

Sl. No.	Subject Type	Subject Code	Subject (Theory)	Teaching Hours			Credit
				L	T	P	
1	OE	MS4342 MS4344	Open Elective – II 1. Nanomaterials 2. Energy Materials	3	0	0	3
2	OE	MS4346 MS4348	Open Elective – III 1. Experimental Techniques in Materials Engineering 2. Non-Destructive Testing of Materials	3	0	0	3
3	OE	MS4350 MS4352	Open Elective – IV 1. Functional Materials 2. Composite Materials	3	0	0	3
			Subject (Sessional)				
4	PSI	MS4742	Seminar on Project/ Seminar	0	0	6	1
5	PSI	MS4642/ MS4644	Project for Product Development – III / Internship Project - II	0	0	12	5
			Total	**9**	**0**	**18**	**15**

Project / Seminar / Internship

GRAND TOTAL CREDITS: 162

Honours in Materials Engineering

Sl. No.	Subject Type	Course Code	Subject (Theory)	Semester	Teaching Hours			Credit
					L	T	P	
1	Honours	MS3175	Physical Metallurgy of Metals and Alloys	5th	3	0	0	3
2	Honours	MS3176	Advanced Engineering Materials	6th	3	0	0	3
3	Honours	MS4179	Materials Selection and Design	7th	3	0	0	3
4	Honours	MS4181	Metallurgical Failure Analysis	7th	3	0	0	3
5	Honours	MS4176	Making and Metallurgy of Stainless Steels	8th	3	0	0	3
			Subject (Sessional)					
1	Honours Lab	MS3576	Microstructural Analysis Laboratory	6th	0	0	3	1.5
2	Honours Lab	MS4575	Metal and Powder Forming Laboratory	7th	0	0	3	1.5
			Total		**15**	**0**	**6**	**18**

Minor in Industrial Metallurgy

Sl. No.	Subject Type	Course Code	Subject (Theory)	Semester	Teaching Hours			Credit
					L	T	P	
1	Minor	MS3265	Introduction to Physical Metallurgy	5th	3	0	0	3
2	Minor	MS3266	Iron Making & Steel Making	6th	3	0	0	3
3	Minor	MS4269	Mechanical Metallurgy	7th	3	0	0	3
4	Minor	MS4271	Materials Characterization Techniques	7th	3	0	0	3
5	Minor	MS4266	Advanced Materials and Processing	8th	3	0	0	3
			Subject (Sessional)					
1	Minor Lab	MS3566	Physical Metallurgy Laboratory	6th	0	0	3	1.5
2	Minor Lab	MS4565	Materials Characterization Laboratory	7th	0	0	3	1.5
			Total		**15**	**0**	**6**	**18**

3rd Semester

Mathematics – III			
Hours/Week L-T-P :	3-0-0	Credits:	3
Course Type :	Mandatory/ Common Course	Course Code:	BH2459

Prerequisite: Basic knowledge of calculus, linear algebra, differential equations, and elementary probability is required.

Course Objectives:

1. Apply numerical methods for solving equations, interpolation, and numerical integration.
2. Solve applied partial differential equations using separation of variables and Fourier series.
3. Explain probability concepts and standard probability distributions.
4. Perform parameter estimation, hypothesis testing, regression, and correlation analysis.

Course Outcome:

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

CO1: Demonstrate the use of common numerical methods such as numerical solutions of equations, interpolation, differentiation and integration etc.

CO2: Recognize mathematical model of heat equations, wave equations and their solution by appropriate method.

CO3: Understand the different terminology in probability and have clear concept on probability distribution functions both in continuous and discrete case.

CO4: Select appropriate statistical tools to investigate a research hypothesis, perform data analysis by applying relevant methodology and interpret result in a variety of settings.

Module-1*:* Elementary Numerical Methods
(7Hours)

Solution of algebraic and transcendental equations by Newton-Raphson and secant method. Interpolation: Lagrange's method, divided difference method, Newton's forward and backward method. Numerical Integration: Trapezoidal and Simpson's Rule.

Module- 2*:* Applied PDE's **(7 Hours)**

Elementary PDE's: separation of variables method to simple problems. One dimensional wave equation: solution by separation of variables and use of Fourier series, D' Alembert's solution of wave equation. Normal forms of PDE's.One dimensional heat equation: solution by Fourier series.

Module-3: Basic Probability and Probability Distributions **(7 Hours)**

Probability spaces, conditional probability, independence, Random variables (discrete and continuous), probability mass and density functions, cumulative distribution functions, moments of random variables, mean and variance.

Discrete Probability distributions: Binomial, Poisson and hyper-geometric distributions. Continuous Probability distributions: exponential, uniform and normal distributions.

Module-4*:* Applied Statistics **(7 Hours)**

Random sampling, estimation of parameters, maximum likelihood estimation, confidence intervals, testing of hypotheses for mean and variance.

Regression and correlation analysis: fitting of straight lines (method of lest squares), correlation coefficient with basic properties.

Text Books:

1. Advanced Engineering Mathematics by E. Kreyszig, John Willey & Sons Inc. 10th Edition.
2. Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers & Keying Ye, “Probability & Statistics for Engineers & Scientists", Eighth Edition, 2007, Pearson Education Inc., New Delhi.

Reference Books:

1. Ordinary and Partial Differential equations by J. Sinha Roy and S. Padhy, Kalyani Publishers.
2. Higher Engineering Mathematics by B. V. Ramana, McGraw Hill Education.
3. Engineering Mathematics by Pal and S. Bhunia, Oxford Publication.
4. Stochastic Processes, 2nd Edition by Roy D. Yates, Rutgers and David J. Goodman, John Wiley and Sons, INC.

COs and POs Mapping

Course Outcome	Expected Mapping with Programme Outcomes *(1- Weak Correlation; 2- Medium correlation; 3- Strong Correlation)*										
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**	**PO-7**	**PO-8**	**PO-9**	**PO-10**	**PO-11**
CO-1	3	3	3	3	3	3	2	-	2	-	2
CO-2	3	3	3	3	3	2	2	-	-	-	2
CO-3	3	3	3	3	3	2	3	-	2	-	-
CO-4	3	3	3	3	3	2	2	-	2	-	2

3rd Semester PC1

Material Science and Engineering			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS2145

Course Objectives:

1. To introduce the fundamental concepts of atomic structure and bonding in solid materials.
2. To explain phase diagrams and heat treatment processes for controlling material properties.
3. To study mechanical behaviour and deformation mechanisms in engineering materials.
4. To familiarize students with the properties and engineering applications of various material classes.

Course Outcomes

Upon successful completion of this course, students will be able to:

CO1: Analyze and interpret the atomic structure and bonding in solids.

CO2: Apply phase diagrams and heat treatment processes to engineering materials.

CO3: Evaluate the mechanical behaviour and deformation mechanisms of materials.

CO4: Assess the properties and applications of various materials in engineering.

Module 1: **(10 Hours)**

Bonding in Solids: Ionic, Covalent, and Metallic bonding, bonding forces and energy, secondary bonding.

Crystal Structure: Space lattices and Bravais lattices, Miller Indices of planes and directions, slip planes and slip directions, stereographic projections.

Selected crystal structures: Pure metals, Diamond and Graphite, coordination in ionic crystals, AB type compounds, Silica, Alumina, Complex Oxides, Silicates. Inorganic glass: Network structure in glasses. Polymeric structures: Thermo plastics, Elastomers, Thermosets, crystallinity in polymers.

Experimental tools & techniques: Metallography (Optical TEM, SEM), X Ray Diffraction, Mechanical Properties and measurements, Thermal analysis.

Module 2: **(10 Hours)**

Principles of Alloy theory: Primary substitutional solid solution, Interstitial solid solution, types of intermediate phases, Ordered-Disordered phenomena. Hume Rothery Rules, Intermetallic compounds, Normal valency compounds, Electron compounds, Interstitial compounds.

Imperfections: Point defects, Vacancies, Interstitialcies, Dislocations; Edge & Screw dislocations; Burgers vector.

Crystallization from the melt: Freezing of a pure metal, plane front and dendritic solidification at a cooled surface, formation of cast structure, gas porosity and segregation, directional solidification.

Diffusion: Fick's First and Second law of diffusion, Atomic model of diffusion,

Nucleation: Homogeneous and Heterogeneous nucleation,

Module 3: **(8 Hours)**

Binary Phase Diagrams: Isomorphous, Eutectic, Peritectic, Eutectoid, Monotectic and Syntectic systems, Phase rule and Lever rule. Iron-Cementite Equilibrium diagram and its applications, Plain carbon and alloy steels, Industrial applications of steels.

Heat treatment of Steels: Annealing, normalizing, hardening, tempering and spheroidising, Isothermal Transformation diagrams for Fe-C alloys and microstructure development.

Module 4: **(8 Hours)**

Alloying of steels, properties of stainless steels, tool steels, bearing steels, Rail steels, Corrosion resistant steels, cast irons; grey, white, malleable and spheroidal cast irons. Copper and copper alloys; brass, bronze and cupro-nickel; Aluminium and Al and Mg base alloys, Nickel based superalloys and Titanium alloys

Text Books:

1. Materials Science and Engineering – A First Course, V. Raghavan, Prentice-Hall of India Private Limited, 2003.
2. Materials Science& Engineering- An Introduction, W. D. Callister, John Wiley& Sons, 2007.
3. Foundations of Materials Science and Engineering, W. F. Smith, Mc Graw Hill, Indian Edition.
4. Introduction to Physical Metallurgy, Sidney H. Avner, McGraw Hill Education.

5. Physical Metallurgy: Principles and Practice, V. Raghavan, PHI.

Reference Books:

1. R.E Reed Hill and Abbaschain, Physical Metallurgy Principles, PWS-Kent Publishing,2004.
2. Vijendra Singh, Physical Metallurgy, Standard Publisher,2008.
3. C. Daniel Yesudian and D.G. Harris Samuel, Scitech Publication, India-2010
4. L. H. Van Vlack, Addison Wisley, Elements of Materials Science and Engineering, Pearson Education India.
5. Materials Science, M.S. Vijaya and G. Rangarajan Mc Graw Hill Education (India)-2014
6. Materials Science and Engineering, G. S. Upadhyaya and Anish Upadhyaya, Viva Books Private Limited, 2006.

CO-PO-PSO Mapping

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	-	-	-	-	-	-	-	-	2	3	2	-
CO2	3	3	3	2	2	2	-	-	-	-	2	3	3	2
CO3	3	3	3	2	2	-	-	-	-	-	2	3	3	2
CO4	2	2	3	2	2	2	-	-	-	-	2	3	2	-

Correlation Level 1: Slight 2: Moderate 3: High

3rd Semester PC2

Metallurgical Thermodynamics and Kinetics			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS2143

Course Objectives:

1. To introduce fundamental thermodynamic principles relevant to metallurgical systems.
2. To explain solution thermodynamics and its application in metallurgical processes.
3. To develop skills in constructing and interpreting phase diagrams for alloys and compounds.
4. To provide an understanding of kinetic concepts and their role in metallurgical process design.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Apply Thermodynamic Principles to Metallurgical Systems

CO2: Analyze Solution Thermodynamics in Metallurgical Contexts

CO3: Construct and Interpret Phase Diagrams for Metallurgical Applications

CO4: Integrate Kinetic Concepts into Metallurgical Process Design

Module 1: **(8 Hours)**

Importance of thermodynamics, Ideal Gas, Energy and Work, Extensive and Intensive Properties;

First Law of Thermodynamics, Internal Energy, Enthalpy, Heat Capacity, Reversible Processes;

Second Law of Thermodynamics, Entropy and equilibrium, Reversibility, Heat Engines;

Statistical Interpretation of Entropy, Boltzmann Equation

Module 2: **(10 Hours)**

Auxiliary Functions Enthalpy, Free Energy, Chemical Potential, Maxwell's Equations, Gibbs-Helmholtz Equation;

Enthalpy as a Function of Temperature and Composition, Third Law of Thermodynamics;

Phase Equilibrium in a One-Component System, Equilibrium between Vapor and Condensed Phase, and between condensed phases;

Gases: Ideal, Real, van der Waals

Module 3: **(10 Hours)**

Raoult's Law and Henry's Law, Activity, Gibbs-Duhem Equation, Properties of Ideal and Non-ideal Solutions, Regular Solutions Activity;

Phase Diagrams of some Binary Systems, Effect of Temperature and Pressure on the Equilibrium Constant for a gas mixture;

Ellingham Diagrams

Module 4: **(8 Hours)**

The Gibbs Phase Rule;

Electrochemistry, Concentration and EMF, Standard Reduction Potentials, Pourbaix Diagrams

Introduction to metallurgical kinetics: heterogeneous reaction kinetics: gas-solid, solid – liquid, liquid – liquid and solid-solid systems. Empirical and semi-empirical kinetics, concept of Johnson – Mehl equation, thermal analysis.

Text Books:

1. Introduction to Thermodynamics of Materials, 5th Edition, David R Gaskell and David E. Laughlin, CRC Press, Taylor and Francis Group, 2017, 6th Edition.
2. Materials Thermodynamics with Emphasis on Chemical Approach, Hae-Geon Lee, World Scientific Publishing Co Inc, 2012.
3. Kinetics of Metallurgical Reactions by H. S. Ray; Oxford and IBH Publishing Co.
4. A Textbook of Metallurgical Kinetics by Ahindra Ghosh and Sudipto Ghosh, PHI.
5. Metallurgical Thermodynamics Kinetics & Numericals, S.K. Dutta, A.B. Lele, S. Chand

Reference Books:

1. Thermodynamics in Materials Science, Robert DeHoff, CRC Press Taylor & Francis Group, 2006.
2. Physical Chemistry of Metals, L.S. Darken and R.W. Gurry, CBS Publishers & Distributors-Delhi.
3. Introduction to Metallurgical Thermodynamics, R.H. Tupkary, T.U. Publishers, Nagpur.
4. Text book of Materials and Metallurgical Thermodynamics, A. Ghosh, Prentice Hall of India Pvt. Ltd.
5. Problems in Metallurgical Thermodynamics & Kinetics by G. S. Upadhyay & R. K. Dube; Pergamon Press.
6. Principles of Metallurgical Thermodynamics by S.K. Bose and S.K. Roy, University Press, IIM series in Metallurgy and Materials Science, 2014.

7. Chemical and Metallurgical Thermodynamics – Part I & II, M.L. Kapoor, NEM CHAND & BORS; Roorkee

CO-PO-PSO Mapping

CO	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7	PO 8	PO9	PO1 0	PO11	PSO1	PSO 2	PSO3
CO1	3	2	-	2	2	-	-	-	-	-	2	3	2	2
CO2	3	3	-	2	2	-	-	-	-	-	2	3	3	2
CO3	3	3	3	2	2	1	-	-	-	-	2	3	3	2
CO4	3	3	3	3	2	2	-	-	-	-	3	3	3	3

Correlation Level 1: Slight 2: Moderate 3: High

3rd semester PC3

Mechanics of Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS2141

Course Objectives:

1. To introduce fundamental concepts of axial loading, stress, and deformation in structural members.
2. To develop the ability to construct and analyze shear force and bending moment diagrams.
3. To equip students with tools to evaluate complex stress and strain using Mohr's Circle.
4. To provide an understanding of plastic deformation and fracture mechanics in materials.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze and solve problems involving axial loading and deformation.

CO2: Construct and interpret shear force and bending moment diagrams.

CO3: Evaluate stress and strain states using Mohr's Circle.

CO4: Apply principles of plasticity and fracture mechanics to material behaviour.

Module 1: **(8 Hours)**

Basic principles of mechanics: Concepts of force and moment of force, conditions of equilibrium, friction.

Mechanics of deformable bodies: Uniaxial loading and deformation, elastic energy - Castigliano's theorems.

Module 2: **(10 Hours)**

Analysis of structures (trusses, beams, columns, shafts): axial force, shear force, bending moment, twisting moment; Analysis of distributed and concentrated loads - differential equilibrium relationship; concentrated loads and singularity;

Module 3: **(10 Hours)**

Concepts of stress and strain: stress at a point, plane stress, principal stress and Mohr's circle of stress in 2D, state of stress in 3D, displacement and strain at a point, plane strain, principal strain, generalized elastic stress-strain relations (tensor forms), tensile test and stress-strain curves (engineering and true), stress concentration, thermal strain, stress and strain invariants, failure criteria.

Module 4: **(8 Hours)**

Concepts of plasticity: flow curve, ideal plastic flow, yield surface and hardening theories, rate dependent plasticity.

Concepts of fracture: modes of fracture, Griffith's theory - strain energy release rate and stress intensity factor.

Text Books:

1. Archer, Cook, Crandall, "Introduction to mechanics of solids", Second edition, McGraw-Hill
2. Dieter, "Mechanical Metallurgy", 3rd edition, McGraw-Hill
3. Ashby and Jones, "Engineering Materials", Butterworth-Heinemann, 2012

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	2	-	-	-	-	-	2	3	2	2
CO2	3	3	2	2	2	-	-	-	-	-	2	3	2	2
CO3	3	3	2	2	2	-	-	-	-	-	2	3	3	2
CO4	3	3	3	2	2	1	-	-	-	-	2	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

SMART FACTORY SYSTEMS			
Hours/ Week L-T-P:	3-0-0	Credits:	2
Course Type:	ACC	Course Code:	MS2147

Course Objectives:

1) To introduce the basics of factory, various techniques used in industry, factory layout and Industrial Revolution.
2) To explain various components of Smart Factory such as AI&ML, IIOT, cloud computing, Digital Twin, Robotics and Automation, 3D printing in details.
3) To explain the needs and principles of Smart factory.
4) To explain how to implement Smart Factory concept in various Industry.

Course outcomes:

At the end the course, the students will be able to

CO1: Know the basic idea about factory and factory layout.

CO2: Identify and analyze the technologies such as IIOT, could computing, AI&ML, digital twin,
Robotics and automation, 3D Printing.

CO3: Understand the principles of Smart factory and Industry 4.0

CO4: Analyze how to implement smart factory concept in various industries.

MODULE-I **(10 hours)**

Introduction to Factory: Activities involved in an Industry, Techniques used in Industry (method study, time study), Productivity, Factory layout: Principles, influencing factors, Types.

Industrial Revolution, Introduction to Industry 4.0 - Profound and Systematic Change – Trends in Industry 4.0

MODULE-II **(10 hours)**

Introduction to Smart Factory, Components of smart factory, Industrial Internet of Things (IIoT), Edge Devices/Gateways, Industrial Networks, Cloud Computing, Data Analytics Tools, Artificial Intelligence (AI) and Machine Learning (ML), Digital Twins, Robotics and Automation Systems, Additive Manufacturing (3D Printing), Human Element and Workforce Transformation.

MODULE-III **(6 hours)**

Need of Smart Factory, levels of smart factory, technologies used in smart factory, benefits and challenges of smart factories, smart factory in IOT, key principles of a smart factory, creating a smart factory.

MODULES-IV **(4 hours)**

Smart Factory in use: Real-World Examples of Smart Factories in Action (**Siemens, Bosch, Johnson & Johnson, DePuy Synthes, Tesla)**, Common Use Cases and Applications. Introduction to Industry 5.0.

Text Books:

1. Martand Telsang, "Industrial Engineering and Production Management", S. Chand.

2. Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", A press, 2016.

Reference Books:

1. Lihui Wang and Andrew YehChing Nee, Collaborative Design and Planning for Digital Manufacturing, Springer-Verlag London Limited, 2009
2. Andrew Yeh Chris Nee, Fei Tao, and Meng Zhang, "Digital Twin Driven Smart Manufacturing", Elsevier Science., United States, 2019.
3. Alp Ustundag and Emre Cevikcan, "Industry 4.0: Managing the Digital Transformation", Springer Series in Advanced Manufacturing., Switzerland, 2017
4. Ronald R. Yager and Jordan Pascual Espada, "New Advances in the Internet of Things", Springer., Switzerland, 2018.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	1	1	3	3	3	-	2	2	1	2	2	1
CO2	3	2	3	2	3	3	3	2	2	2	2	2	2	3
CO3	3	1	2	1	3	3	3	2	3	2	1	2	2	3
CO4	3	2	3	2	3	3	3	2	2	2	2	2	2	3

Correlation Level 1: Slight 2: Moderate 3: High

Organizational Behaviour			
Hours/Week L-T-P :	3-0-0	Credits:	2
Course Type :	Mandatory/ Common Course	Course Code:	BH2437

Prerequisites: Basic understanding of psychology, human behaviour, and communication skills in an organizational or social context.

Course Objectives:

1. To understand how individual, groups and structure have impacts on the organizational effectiveness.
2. To learn the basic concepts of Organizational Behavior and its applications in contemporary organizations.
3. To appreciate the theories and models of organizations in the workplace to creatively and innovatively engage in solving organizational challenges.
4. To learn and appreciate different cultures and diversity in the workplace.

Course Outcome:

CO1: Able to analyse and compare different models used to explain individual behaviour related to motivation.

CO2: Understanding how individual, groups and structure have impacts on the organizational effectiveness.

CO3: Learning the basic concepts of Organizational Behavior and its applications in contemporary organizations.

CO4: Learning and appreciating the different cultures and diversity in the workplace. Understanding the group dynamics and demonstrating skills required to work in teams.

Module-1: Individual Level **(11 Hours)**

The study of Organizational Behaviour: Definition, Meaning, Why study OB; Learning – Principles of learning and learning theories: Classical Conditioning and Operant conditioning, Personality- Meaning, Determinants, Types of Personality, Perception- Perceptual Process, perceptual errors, Attitude (cognitive dissonance), Motives and Motivation-Nature and Process, Theories of Motivation (Herzberg, Maslow, ERG, Vroom's expectancy theory) .

Module-2: Group level-I **(6 Hours)**

Groups in Organizations –Nature, Types, Group formation, Determinants, factors contributing to Group Cohesiveness, Group Decision Making Process: Brainstorming and Nominal group technique

Module-3: Group level-II **(6 Hours)**

Types of Leadership- Effective Leadership, Styles of leadership: Autocratic, Democratic and Lassiez faire, Leadership Theories-Trait Theory and Contingency Theory(SLT, Path-goal

theory and Fred Fiedler's model), Conflict- Types of conflict, Conflict Resolution Techniques, Emotional Intelligence, Emotions and Stress in workplace.

Module-4: Structural level **(7 Hours)**

Organizational Culture: Cultural dimension and organizational effectiveness, Organizational Change: Types of change, Process of change, Reasons to change, Resistance to change and managing resistance to change.

Text Books:

1. Stephens P Robbins, Organisational Behaviour, PHI
2. K. Aswatthappa, Organisational Behaviour, HPH

Reference Books:

1. Kavita Singh, Organisational Behaviour, Pearson
2. D.K. Bhttacharya, Organisational Behaviour, OUP
3. Pradeep Khandelwal, Organisational Behaviour, TMH
4. Keith Davis, Organisational Behaviour, McGraw Hill
5. Nelson Quick, ORGB, Cengage Learning

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2
CO1	2	1	-	-	-	2	3	2	2	2	-	2	-
CO2	2	1	-	-	-	2	2	3	3	3	-	2	-
CO3	2	-	-	-	-	3	3	3	2	3	-	2	-
CO4	2	1	-	-	-	3	2	2	2	2	-	2	-

Correlation Level 1: Slight 2: Moderate 3: High

Practical Sessional Subjects 3rd Semester

Mechanical Testing Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Laboratory Course	Course Code:	MS2541

Course Objectives:

1. To provide hands-on training in standard mechanical testing techniques for material property evaluation.
2. To develop the ability to analyze material response under various loading conditions.
3. To introduce non-destructive testing methods for identifying and characterizing material defects.
4. To enable comparison of mechanical performance across different materials based on test results.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Perform and interpret standard mechanical tests to evaluate material properties.

CO2: Analyze material behaviour under different loading conditions and correlate test results with material performance.

CO3: Apply non-destructive testing methods to detect and characterize material defects.

CO4: Evaluate and compare the mechanical performance of materials.

Suggested list of experiments:

(Minimum 08 experiments)

1. Study of testing machines: Hydraulic and Servo hydraulic universal testing machines, hardness testing machines, impact testing machines, fatigue testing machines.
2. To determine the Vickers Hardness Number of the given Samples.
3. To determine the Brinell Hardness Number of the given Samples.
4. To determine the Rockwell Hardness of the given samples.
5. To determine the impact strength of the given samples by Charpy and Izod Impact Tests.
6. To determine the tensile properties of the given materials using Universal Testing Machine (UTM) —yield strength, tensile strength, % elongation, % reduction of area.
7. To determine the compression strength of the given sample.
8. To determine the fatigue strength of the given sample.

9. Fracture mechanics test.
10. To determine the drawability of aluminium /steel sheet by Erichsen cup test.
11. Three- point bend test of non - metallic materials
12. Impact testing of steels/ non - ferrous alloys/ non - metallic materials
13. To determine the cracks in a sample using the magnetic crack detector.
14. Wear studies of different carbon steels.

Appropriate ASTM standards to be followed.

Text Books:

1. Mechanical Metallurgy by George E Dieter, McGraw-Hill Education; 3 edition June 1986.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	3	2	–	–	–	2	–	2	3	3	2
CO2	3	3	2	3	2	–	–	–	2	–	2	3	3	2
CO3	2	2	2	3	3	–	2	–	2	–	2	2	3	3
CO4	3	3	2	2	2	–	–	–	3	–	2	3	3	2

Correlation Level 1: Slight 2: Moderate 3: High

3rd Semester Sessional

Metallography Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Laboratory Course	Course Code:	MS2543

Course Objectives:

1. To introduce techniques for metallographic sample preparation and microscopic examination.
2. To develop skills in interpreting microstructures of metals, alloys, and heat-treated steels.
3. To study the influence of mechanical processing and heat treatment on microstructural changes.
4. To train students in identifying and evaluating metallurgical defects and failures in components.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Perform metallographic sample preparation and microscopic examination of metals and alloys.

CO2: Analyze and interpret microstructures of pure metals, alloys, and heat-treated steels.

CO3: Analyze the effects of mechanical processing and heat treatment on microstructural evolution.

CO4: Detect and evaluate metallurgical defects and failures in cast, wrought, and welded components.

List of Experiments:

(Minimum 08 experiments)

1. Study of Metallurgical Microscope.
2. Metallographic preparation of metals and alloys.
3. Determination of cooling curves of pure metals like Pb, Zn and Sn.
4. Microstructure of pure metals.

5. Microstructure of isomorphous alloys belonging to Cu-Zn, Cu-Sn and Cu-Ni systems.
6. Effect of cold working on hardness and microstructures of metals like Cu.
7. Recrystallisation and grain growth in cold worked and annealed Cu.
8. Microstructure of plain carbon annealed steels with variation in carbon content (Hypoeutectic, eutectic, Hypereutectic).
9. Microscopic examination of cast, wrought and welded structures; defects and failures in components.

Text Books:

1. R. Haynes, 1984, Springer science + Business Media, New York
2. Douglas B. Murphy, 2001, Wiley-Liss, Inc. USA

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	3	3	–	–	–	2	–	2	3	3	2
CO2	3	3	2	3	2	–	–	–	2	–	2	3	3	2
CO3	3	3	2	3	2	–	–	–	2	–	2	3	3	3
CO4	3	3	3	3	2	2	2	2	3	2	2	3	3	3

Correlation Level 1: Slight 2: Moderate 3: High

3rd Semester Sessional

Materials Chemistry Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Laboratory Course	Course Code:	MS2545

Course Objectives:

1. To introduce classical wet chemical methods for quantitative analysis of ferrous and non-ferrous alloys.
2. To train students in instrumental techniques for elemental analysis.
3. To develop skills in interpreting chemical analysis data for evaluating material composition and quality.
4. To promote safe laboratory practices and proper use of chemicals and analytical equipment.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Perform quantitative chemical analysis of ferrous and non-ferrous alloys using classical wet chemistry methods.

CO2: Analyze and apply instrumental techniques for elemental analysis of metals and alloys.

CO3: Analyze and interpret chemical analysis data to assess material composition and quality.

CO4: Demonstrate safe laboratory practices and proper handling of chemicals and analytical instruments.

1. Chemical analysis to identify and quantify different elements in ferrous and nonferrous alloys by wet chemistry routes

(Minimum 06 experiments)

a) Determination of Cu in Brass Sample.
b) Determination of Fe in Iron Ore.
c) Determination of Mn in Steel.
d) Determination of Cr in steel.
e) Determination of Si in cast iron.
f) Determination of carbon and sulphur in steel.
g) Determination of Ca in Limestone.

2. Study of principles and equipment related to chemical analysis of ferrous and nonferrous alloys by instrumental methods:

(Minimum 02 methods)

a) Atomic Absorption Spectroscopy (AAS)
b) Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES)
c) Inductively Coupled Plasma Mass Spectrometry (ICP-MS)
d) X-ray Fluorescence Spectroscopy (XRF)
e) Elemental Analysis by Combustion (e.g., CHN analysis)

Text Books:

1. A text book of metallurgical analysis, B C Aggarwal, Khanna Publishers (2002)
2. Instrumental methods of analysis, Willard, CBS Publishers & Distributors (2004)

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	3	2	–	–	–	2	–	2	3	3	2
CO2	3	3	2	3	3	–	–	–	2	–	2	3	3	3
CO3	3	3	2	3	2	–	–	–	2	–	2	3	3	3
CO4	2	2	1	2	2	3	3	2	2	2	2	2	2	2

Correlation Level 1: Slight 2: Moderate 3: High

SMART FACTORY LABORATORY			
Hours/ Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	ACC	Course Code:	MS2547

Prerequisites: Industrial Engineering and Industrial Revolution.

Course Objectives:

1) To introduce the basics of Smart factory and its various components.
2) To let the students learn about Design software (SolidWorks/ ANSYS)
3) To manufacture products by using 3D Printers.
4) To test and validate PLC code using a digital twin before deploying it to physical hardware.

Course outcomes:

At the end the course, the students will be able to

CO1: Know the basic idea about Smart factory and Industry 4.0.

CO2: Learn about SolidWorks software and 3D printer.

CO3: learn the use of cloud computing and IOT.

CO4: build a digital twin for throughput analysis.

List of experiments:

Any six of the following experiments.

1. Introduction to Industrial Revolution and Smart Factory Laboratory.
2. Basic Automation and HMI Control.
3. Develop a Job by 3D Printer using CAD software.
4. Study of Automated Guided Vehicle for material transport.
5. Inspection and Quality checking various parts at its work station.
6. Product Tracking with Industrial RFID.
7. Building a Digital Twin for Throughput Analysis.
8. Cloud Connectivity and IoT Analytics with Insights Hub.
9. Development of IOT app for milling and drilling machine.
10. Experiment on AR & VR.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	-	1	1	1	1	1	2	3	2	2
CO2	3	2	1	2	-	1	1	3	2	1	2	2	2	2
CO3	3	2	2	2	-	2	2	2	1	1	2	2	2	1
CO4	2	2	1	2	-	2	2	2	2	1	2	2	2	1

Correlation Level **1: Slight** **2: Moderate** **3: High**

4th Semester

4th semester PC4

Non-Ferrous Metal Extraction			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS2142

Prerequisite:

Metallurgical Thermodynamics and Kinetics

Course Objectives:

1. To introduce the fundamentals of mineral processing and ore beneficiation techniques.
2. To provide a foundation in thermodynamic and kinetic principles relevant to metal extraction.
3. To explain the general methods of metal extraction and refining using pyrometallurgy, hydrometallurgy, and electrometallurgy.
4. To study the extraction processes of important non-ferrous metals such as Al, Cu, Zn, U, and Rare Earths.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Apply the principles of mineral processing for the beneficiation of different ores and minerals.

CO2: Apply the basic thermodynamics and kinetics principles for the extraction of metals.

CO3: Explain the principles of general extraction and refining of metals in Pyrometallurgy, Hydrometallurgy, and Electrometallurgy.

CO4: Apply the principles for the extraction of non-ferrous metals like Al, Cu, Zn, U, and Rare Earth.

Module 1: **(8 Hours)**

Mineral Processing: Ore and ore body, parameters defining economy of ore processing, Liberation, communication, crushing, grinding, sizing, classification, Principles of minerals beneficiation such as heavy media separation, jigging, tabling, magnetic and electrostatic separation, Flotation, Solid – Liquid separation.

Module 2: **(10 Hours)**

Pyrometallurgy: Role of Ellingham diagram and phase stability diagrams, drying, calcinations, roasting and its types, smelting and its types.

Pyrometallurgical extraction of copper: flowsheet, flotation, roasting, matte smelting, converting, refining.

Pyrometallurgical extraction of nickel: flowsheet, roasting, matte smelting,

Pyrometallurgical extraction of zinc and lead: flowsheet, flotation, roasting, sintering, smelting, refining,

Extraction of Titanium: Flowsheet – Kroll's process, carbochlorination,

Extraction of Magnesium.

Module 3: **(8 Hours)**

Hydro & Electrometallurgy: Principles of Leaching, simple dissolution, oxidative and reductive leaching, types of leaching in sites leaching, heap leaching, vat leaching, agitation leaching, pressure leaching, bio leaching solution extraction, ion exchange, Electrode potential, Electrochemical cell, electrochemical series, Eh – pH diagram. Faradays' Law, Cell voltage, current density, current efficiency, Electro-winning, Electro refining, direct electrowinning, fused – salt electrolysis.

Module 4: **(10 Hours)**

Hydrometallurgy of Zinc: flowsheet flotation roasting, solution purification, electrowinning, **Pressure – Leaching – EW**.

Hydrometallurgy of copper: flowsheet, heap leching/bioleach/roast – leach, solvent extraction, electrowinning.

Hydrometallurgy of nickel: (A) Pressure leaching electrowinning, (B) Direct – electrowinning of Mette – anode, (C) Lattierite processing (1) H_2SO_4 pressure leaching and (2) Roasting – Ammoniaized leaching – BNC precipitation,

Metallurgy of Uranium: flowsheet in-situ / heap/ vat – leaching – solution purification, production of UO_2,

Metallurgy of Au and Ag: flowsheet – leaching – purification – EW,

Metallurgy of Aluminium – Bayers process, Hall – Heroult process, anode preparation, electrolyte, energy consumption,

Metallurgy (fused salt – EW) of Mg, Na: flowsheet.

Text Books:

1. Principles of Extractive Metallurgy by T. Rosenqvist. McGraw Hill.
2. Principles of Extractive Metallurgy by Ahindra Ghosh and H. S. Ray

3. H. S. Ray, R. Sridhar, K. P. Abraham, Extraction of Non-ferrous Metals, Affiliated East-West Press Pvt. Ltd.
4. Textbook of Mineral Processing, D.V. Subba Rao, Scientific Publishers, 2017.

Reference Books:

1. Unit Processes of Extractive Metallurgy by R.D. Phelke, Elsevier Science Ltd, 1973.
2. Principles of Extractive Metallurgy, Vol. 1-4, F. Habashi, McGraw-Hill, 1993
3. Chemical Metallurgy: Principles and Practice, C. K. Gupta, John Wiley & Sons, 2006.
4. Wills' Mineral Processing Technology, B.A. Wills and J. Finch, Elsevier, 2016, 8th Edition
5. Principles of Mineral Dressing by A.M. Gaudin, Tata McGraw-Hill Publishing Company, 1980.
6. M. Shamsuddin, Physical Chemistry of Metallurgical Processes, Willey
7. C. Bodsworth, Extraction and Refining of Metals, CRC Press
8. Fundamentals of Metallurgical Processes by L. Coudurier, D. W. Hopkins and I. Wilkomirsky, Pergamon.
9. Metallurgical Problems by A. Butts, Johnston Press, 2007
10. Element of Ore Dressing by A.F. Taggert, Wiley.
11. Mineral Processing Technology, S.K. Jain, CBS Publisher, 2001, 2nd Edition

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	3	2	2	–	2	2	1	2	3	3	3
CO2	3	3	2	3	2	2	–	–	2	–	2	3	2	3
CO3	3	3	2	2	2	2	–	–	2	–	2	3	2	3
CO4	3	3	2	2	2	2	1	–	2	–	2	3	2	3

Correlation Level 1: Slight 2: Moderate 3: High

4th Semester PC5

Iron and Steel Making			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS2144

Prerequisite:

Metallurgical Thermodynamics and Kinetics

Course Objectives:

1. To explain the fundamental physical and chemical processes involved in ironmaking and steelmaking.
2. To develop an understanding of how process parameters affect iron and steel production.
3. To introduce methods for quality control in iron and steel manufacturing.
4. To build problem-solving skills in reaction kinetics and composition control relevant to the industry.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Describe the physical and chemical processes that take place during ironmaking and steelmaking

CO2: Analyze the effect of change in process parameters in ironmaking and steelmaking processes

CO3: Explain the methods for the control of quality in iron and steel production

CO4: Solve numerical problems involving reaction kinetics and composition control

Module 1: **(10 Hours)**

History of iron and steel making

Overview of Blast Furnace Ironmaking and modern steelmaking

Blast Furnace Ironmaking:

Physical Chemistry of Blast Furnace Reactions; Thermal and Chemical features of the Blast Furnace; Internal zones and Gas Flow in Blast Furnaces;

Raw materials – coke, iron ore and agglomerates

Blast Furnace productivity, fuel efficiency and modern developments

Blast Furnace Products and their Utilisation

Module 2: **(10 Hours)**

Alternative Ironmaking

Coal-based sponge iron processes: sponge iron production in Rotary Kilns; Coal based processes using Rotary Hearth Furnaces.

Gas-based processes: Reforming of natural gas; Finmet process; HYL I process; gas based shaft furnace processes.
Smelting Reduction processes: Corex process; Hismelt process, Romelt process; Finex process; Fastmelt process, ITmk3; Tecnored process, Mini Blast Furnace.

Module 3: **(10 Hours)**

Steelmaking

Physical Chemistry of Primary Steelmaking, BOF Plant Practice, Metallurgical features of Oxygen Steelmaking, Process Control for Basic Oxygen Steelmaking, Basic Open Hearth Steelmaking, Electric Arc Furnace Steelmaking.

Module 4: **(8 Hours)**

Secondary Steelmaking: Introduction, Inert gas Purging, Deoxidation of liquid steel, Degassing and Decarbuisation of liquid steel, Desulphurisation in secondary steelmaking, Clean steel technology.
Casting of Liquid Steel: Ingot casting of Steel, Continuous casting of Steel

Text Books:

1. Ironmaking and steelmaking: Theory and Practice, Ghosh Ahindra, Chatterjee Amit, PHI.
2. A first course in iron and steel making, Dipak Mazumdar, Orient Blackswan Pvt. Ltd.

Reference Books:

1. Integrated Iron and Steel Making by Amit Chatterjee, Krishnakant Prasad, Khanna Publishers.
2. Extractive Metallurgy 1: Basic Thermodynamics and Kinetics, Alain Vignes (ISTE Ltd.,)
3. Extractive Metallurgy 2: Metallurgical Reaction Processes, Alain Vignes (ISTE Ltd.,)
4. Extractive Metallurgy 3: Processing Operations and Routes, Alain Vignes (ISTE Ltd.,)
5. Production of iron (Theory and Practice), R. H. Tupkary, Khanna Publishers (2022)
6. Production of steel (Theory and Practice), R. H. Tupkary, Khanna Publishers (2022)

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	2	2	–	–	2	–	2	3	2	2
CO2	3	3	2	3	2	2	–	–	2	–	2	3	2	3
CO3	3	3	3	2	2	2	2	1	2	1	2	3	3	3
CO4	3	3	2	3	2	–	–	–	2	–	2	3	2	2

Correlation Level **1: Slight** **2: Moderate** **3: High**

4th semester PC6

Transport Phenomena			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS2146

Course Objectives:

1. To provide to the student a sufficient background to be able to understand the fundamentals of transport phenomena related to metallurgical processes
2. To provide conceptual knowledge to the student for comprehending governing equations and assumptions used in the analysis of transport processes
3. To transfer knowledge to the student regarding three fundamental transport processes such as momentum, heat and mass, including conservation and constitutive equations
4. To provide to the student a sufficient background of solution methods to be able to solve a variety of problems related metallurgical transport phenomena

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain fundamental concepts of fluid mechanics, including fluid types, flow characteristics, and apply continuity and Bernoulli's equations to solve fluid flow problems.

CO2: Perform dimensional analysis using Rayleigh's method and Buckingham's π theorem to derive dimensionless numbers and analyze their significance in fluid flow and heat/mass transfer phenomena.

CO3: Apply the principles of mass transfer, including Fick's laws of diffusion and mass transfer coefficients, to model and solve mass transfer problems in engineering systems.

CO4: Analyze heat transfer mechanisms—conduction, convection, and radiation—and solve related steady and unsteady state heat transfer problems using analytical and numerical methods.

Module 1: (9 Hours)

Fluid Flow: Classification of fluids, ideal & real, Newtonian & Non-Newtonian, Newton's law of viscosity. Types of fluid flow – streamline & turbulent, continuity equation for incompressible and compressible fluid and its application. Concept of velocity bounds layer. Bernoulli's equation and its application for flow measurement by venturi meter, orifice meter, pilot tube, and rotameter.

Module 2: **(10 Hours)**

Dimensional analysis using Rayleigh's method of indices and Buckingham's pie theorem. Example of pressure gradient analysis, mass transfer co-efficient & convective heat transfer coefficient, concept of similar and dimensionless criteria. Dimensionless groups & their significance. Derivations, Problems. Pressure drop & friction factor in various configurations, flow in packed bed & fluidized bed. Free and partially restricted jets, high-velocity fluid jets.

Module 3: **(7 Hours)**

Mass Transfer: Law of diffusion, Fick's 1 & 2 law, its derivation with their application, the concept of mass transfer co-efficient & concentration boundary layer, Interfacial mass transfer, overall mass balance. Numerical Problems.

Module 4: **(10 Hours)**

Heat Transfer: Internal & External modes of heat transfer, steady state heat conduction in monolayer and composite flat walls & cylinders. Unsteady state heat conduction, thin & massive body heating & cooling. Finite difference method in solving unsteady state heat conduction. Natural and forced convection, heat transfer coefficient, and thermal boundary layers are some examples of connective co-relations. Law of radiation – Steffan-Boltzmann's law, Kirchoff's law & Lambarth's law, Black & grey body concepts, view factor, Radiation from flames & gases. Radiation between simple surfaces with & without absorbing gas media. Radiation shields. Overall Heat transfer coefficient.

Text Books:

1. G.H. Geiger and D.R. Poirier, Transport Phenomena in Materials Processing, Addison Wesley
2. R.B. Bird, W.E. Stewart and E.N. Lightfoot, Transport Phenomena, Wiley

Reference Books:

1. J.R. Welty, R.E. Wilson and C.E. Wicks, Fundamentals of Momentum Heat and Mass Transfer, Wiley
2. Snehanshu Pal, Anshuman Patra, P R Padhee, Process Modeling for Steel Industry, IK Publishers

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
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CO2	3	3	2	3	2	–	–	–	2	–	2	3	2	2
CO3	3	3	2	3	2	1	–	–	2	–	2	3	3	3
CO4	3	3	2	3	3	1	–	–	2	–	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

4th Semester PC7

Materials Processing			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS2148

Course Objectives:

1. To study the fundamentals of deformation processing related to various manufacturing processes
2. To obtain knowledge of various metal joining processes of various engineering alloys
3. To analyze the concepts associated with solidification and its physical metallurgy
4. To obtain the basic knowledge of processing of ceramic and glassy materials and their comparison with other materials

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the principles of plastic deformation and various metal forming processes such as rolling, forging, extrusion, wire drawing, and sheet metal working under different temperature regimes (cold, warm, hot).

CO2: Describe and classify different welding techniques, understand the metallurgy of welding including heat-affected zones (HAZ), welding pool solidification, and evaluate welding stresses and stress-relief treatments.

CO3: Illustrate the fundamentals of metal casting processes including moulding methods, melting techniques, gating and risering design, and identify and troubleshoot common casting defects.

CO4: Analyze the powder metallurgy process, including powder characteristics, compaction, sintering, and assess the applications and benefits of powder metallurgy compared to conventional metal processing methods.

Module 1: **(9 Hours)**

Principles of plasticity related to metal forming, cold, warm, and hot working, dynamic recovery and recrystallization. Basic metal forming processes such as Rolling, Forging, Extrusion, Wire Drawing, Sheet metal working.

Module 2: **(10 Hours)**

Theory and classification of welding processes Gas, arc, resistance, pressure, submerged arc, TIG, MIG, plasma arc and electron beam welding including spot welding laser welding and diffusion welding.

Metallurgy of welding of structural steels, HAZ. Metallurgy of fusion welding of ferritic and austenitic steels, cast iron etc. welding pool solidification. Welding stresses and stress relieving treatments.

Brazing and soldering. Joining of ceramics and plastics.

Module 3: **(10 Hours)**

Introduction to metal casting, Moulding methods, materials and processes, with special reference to patterns, sand and binders. Solidification of short & long freezing range alloy castings, Gating and Risering of castings.

Melting practices for ferrous and non-ferrous alloys-Cupola, rotary furnace, induction furnace, crucible furnace melting.

Casting defects and remedy. Special casting processes.

Module 4: **(8 Hours)**

Basic processes in Powder Metallurgy, Characteristics of powders. Compaction in rigid dies. Sintering of metal powders. Application of powder metallurgy products-their relative advantages.

Comparison of processing and applications of different materials

Text Books:

1. Principles of Metal Casting by R. W. Haine, C. Loper, and P. C. Rosenthal. McGraw Hill Education, 2001
2. Mechanical Metallurgy by George E. Dieter, McGraw Hill
3. Welding and Welding Technology by Little Richard L., McGraw-Hill
4. Powder Metallurgy: Science, Technology, and Materials by Anish Upadhya and G.S. Upadhya, Universities Press
5. Powder Metallurgy: Science, Technology and Applications – P.C. Angelo, R. Subramanian, Prentice Hall India Learning Pvt. Ltd., (2008)

Reference Books:

1. Powder Metallurgy Science by R.M. German
2. Powder Metallurgy: An Advanced Technique of Processing Engineering Materials by B.K. Datta, PHI.

CO-PO-PSO Mapping

CO	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO10**	**PO11**	**PSO 1**	**PSO 2**	**PSO 3**
CO1	3	2	3	2	2	2	–	–	2	1	2	3	2	3
CO2	3	2	3	2	2	2	2	1	2	1	2	3	3	3
CO3	3	2	3	2	2	2	1	1	2	–	2	3	2	3

CO4	3	2	2	2	2	2	–	–	2	–	2	3	2	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

Digital Manufacturing and Industry 4.0			
Hours/Week L-T-P :	3-0-0	Credits :	2
Course Type :	Advanced Competency Course	Course Code:	MS2125

Prerequisites: Basic knowledge of manufacturing processes, industrial engineering, computer fundamentals, and familiarity with supply chain concepts.

Course Objectives:

1. Introduce the fundamentals and practical significance of digital manufacturing, including its evolution and future potential.
2. Explain digital product lifecycle management, digital supply chains, and their role in efficient production systems.
3. Describe key technologies and principles of smart factories and their integration with IoT and cybersecurity.
4. Explore the concepts, implementation, and applications of digital twins in modern manufacturing environments.

Course Outcomes:

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

CO1: Impart knowledge to use various elements in the digital manufacturing.
CO2: Differentiate the concepts involved in digital product development life cycle process and supply chain management in digital environment.
CO3: Select the proper procedure of validating practical work through digital validation in Factories.
CO4: Implementation the concepts of IoT and its role in digital manufacturing.

Module-1 Introduction **(10 Hours)**

Need – Overview of Digital Manufacturing and the Past – Aspects of Digital Manufacturing: Product life cycle, Smart factory, and value chain management – Practical Benefits of Digital Manufacturing – The Future of Digital Manufacturing.

Module-2 Digital Life Cycle & Supply Chain Management **(12 Hours)**

Collaborative Product Development, Mapping Requirements to specifications – Part Numbering, Engineering Vaulting, and Product reuse – Engineering Change Management, Bill of Material and Process Consistency – Digital Mock up and Prototype development – Virtual testing and collateral. Overview of Digital Supply Chain - Scope& Challenges in Digital SC - Effective Digital Transformation - Future Practices in SCM.

Smart Factory – Levels of Smart Factories – Benefits – Technologies used in Smart Factory – Smart Factory in IoT- Key Principles of a Smart Factory – Creating a Smart Factory – Smart Factories and Cybersecurity.

Module-3 Industry 4.0 **(8 Hours)**

Introduction – Industry 4.0 –Internet of Things – Industrial Internet of Things – Framework: Connectivity devices and services – Intelligent networks of manufacturing – Cloud computing – Data analytics –Cyber physical systems –Machine-to-Machine communication – Case Studies.

Module-4 Study of Digital Twin: Basic Concepts **(8 Hours)**

– Features and Implementation – Digital Twin: Digital Thread and Digital Shadow- Building Blocks – Types – Characteristics of a Good Digital Twin Platform – Benefits, Impact & Challenges – Future of Digital Twins.

Text Books:

1. Zude Zhou, Shane (Shengquan) Xie and Dejun Chen, Fundamentals of Digital Manufacturing Science, Springer-Verlag London Limited, 2012.
2. Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", A press, 2016.

Reference Books:

1. Lihui Wang and Andrew Yeh Ching Nee, Collaborative Design and Planning for Digital Manufacturing, Springer-Verlag London Limited, 2009
2. Andrew Yeh Chris Nee, Fei Tao, and Meng Zhang, "Digital Twin Driven Smart Manufacturing", Elsevier Science., United States, 2019.
3. Alp Ustundag and Emre Cevikcan, "Industry 4.0: Managing The Digital Transformation", Springer Series in Advanced Manufacturing., Switzerland, 2017
4. Ronald R. Yager and Jordan Pascual Espada, "New Advances in the Internet of Things", Springer., Switzerland, 2018.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	-	1	1	3	3	-	1	2	2	2	2	2	1
CO2	3	2	3	1	3	3	2	2	2	2	2	2	2	3
CO3	3	-	3	1	3	3	2	-	3	2	2	2	2	3
CO4	3	2	2	2	3	3	2	2	2	2	2	2	2	3

Correlation Level 1: Slight 2: Moderate 3: High

ENGINEERING ECONOMICS			
Hours/Week L-T-P :	3-0-0	Credits :	2
Course Type :	HS	Course Code:	BH2439

Prerequisite: Basic understanding of mathematics and introductory business or economics concepts.

Course Objectives:

1. To provide foundational knowledge on the time value of money, depreciation, and economic evaluation of projects.
2. To introduce key economic concepts including demand, supply, inflation, and national income.
3. To analyze cost and revenue relationships and understand market structures.
4. To relate economic theory to engineering decision-making in project evaluations and resource allocation.

Course Outcomes (COs):

Upon successful completion, the student will be able to:

CO1: Apply time value of money and economic equivalence principles to evaluate engineering alternatives.

CO2: Analyze project viability using economic methods like present worth, annual worth, and IRR.

CO3: Explain core economic concepts such as inflation, national income, unemployment, and banking systems.

CO4: Evaluate the influence of demand, supply, and market structures in decision-making.

Module-1 (6 Hours)

Time value of money- Interest - Simple and compound, nominal and effective rate of interest, Cash flow diagrams, Principles of economic equivalence.

Evaluation of engineering projects-Present worth method, Future worth method, Annual worth method, Internal rate of return method, Cost benefit analysis for public projects.

Depreciation- Depreciation of capital assert, Causes of depreciation, Methods of calculating depreciation (Straight-line method, Declining balance method), after tax comparison of project.

Module-2 (8 Hours)

Cost and revenue concepts, Basic understanding of different market structures, Determination of equilibrium price under perfect competition (Simple numerical problems to be solved), Break Even Analysis-linear approach (Simple numerical problems to be solved).

Banking -Commercial bank, Functions of commercial bank, Central bank, Functions of Central Bank.

Inflation-Meaning of inflation, types, causes, measures to control inflation.

National Income-Definition, Concepts of national income, Method of measuring national income.The Circular Flow of Income, Different measures of National Income, GNP, GDP. Concept of Money and its function; Unemployment, its types, causes and Stagflation; Exchange Rate and its determination.

Module-3 (6 Hours)

Engineering Economics- Nature, Scope, Basic problems of an economy, Micro Economics and Macro Economics.

Demand- Meaning of demand, Demand function, Law of Demand and its exceptions, Determinants of demand, Demand Estimation and Forecasting, Elasticity of demand & its measurement (Simple numerical problems to be solved)

Module-4 (6 Hours)

Supply-Meaning of supply, Law of supply and its exception, Determinants of supply, Elasticity of supply, Determination of market equilibrium (Simple numerical problems to be solved).

Production-Production function, Laws of returns: Law of variable proportion, Law of returns to scale.

Basic Concepts of Market; Monopoly, Perfect Competition, Oligopoly and Monopolistic Competitive Market.

Text Books

1. Riggs, Bedworth and Randhwa, “Engineering Economics”, McGraw Hill Education India
2. Deviga Vengedasalam “Principles of Economics”, Oxford University Press.

Reference Books:

1. William G. Sullivan, ElinM. Wicks, C. Patric Koelling, “Engineering Economy”, Pearson
2. R. Paneer Selvam, “Engineering Economics”, PHI
3. S.P. Gupta, “Macro Economics”, TMH.
4. S.B. Gupta, “Monetary Economics”, Sultan Chand and Co.
5. Mankiew N. G, “Principles of Microeconomics”, Eighth Edition, Cengage Learning, 2016.
6. Sikdar, S, “Principles of Microeconomics”, Third Edition, OUP, 2020.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO12	PSO 1	PSO 2	PSO 3
CO 1	3	3	3	3	1	1	1	2	3	3	2	1	2	2
CO 2	3	2	3	3	1	-	2	1	3	3	2	1	2	1
CO 3	3	3	2	2	1	-	3	2	3	2	2	1	1	2

CO 4	2	2	3	2	1	-	3	2	2	3	2	1	2	2

Correlation Level **1: Slight** **2: Moderate** **3: High**

4th Semester Sessional

Mineral Dressing Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Laboratory Course	Course Code:	MS2542

Course Objectives:

1. To provide hands-on experience in size reduction and particle size analysis of metalliferous ores.
2. To train students in gravity concentration techniques and evaluate their separation efficiency.
3. To demonstrate the principles and procedures of froth flotation for ore beneficiation.
4. To introduce magnetic separation techniques and assess their effectiveness in mineral separation.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Apply size reduction techniques using crushers and grinders, and analyze the particle size distribution of metalliferous ores.

CO2: Apply gravity concentration techniques such as the Wilfley Table to separate minerals based on differences in density and evaluate separation efficiency.

CO3: Demonstrate the principles and operation of froth flotation for the beneficiation of ores and perform flotation experiments to enhance ore quality.

CO4: Apply magnetic separation principles and practice separating magnetic and non-magnetic materials, assessing the separation efficiency.

List of Experiments:

(Minimum 08 experiments)

1. To study the size distribution of a metalliferous ore by using a Test Sieve Stack.
2. To study the size distribution of a metalliferous ore by using a Vibratory Shaker.
3. To study a Jaw Crusher and determine the average size and reduction ratio of crushing a metalliferous ore.
4. Crushing of ore/ coal in a roll crusher and to study the size analysis of the product.
5. Crushing of ore/ coal in a gyratory crusher/ pulveriser and to study the size analysis of the product.
6. Crushing of ore/ coal in a cone crusher and to study the size analysis of the product.

7. To study a Ball Mill and determine the average size and reduction ratio of grinding a metalliferous ore.
8. To study the Hammer mill, and determine the average size and reduction ratio of grinding a metalliferous ore.
9. To study the Wilfley Table and study the underlying principle.
10. To separate a mixture of two minerals of different densities by gravity concentration using Wilfley Table and determine the weight and density of each fraction of the products.
11. To study the principle of Froth Flotation Cell
12. Beneficiation of a metalliferous ore using flotation cell.
13. To study the principle of a magnetic separation unit,
14. To separate a mixture of iron and sand using magnetic separator and determine its efficiency.

CO-PO-PSO Mapping

CO	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO10**	**PO11**	**PSO 1**	**PSO 2**	**PSO 3**
CO1	3	3	2	3	2	1	–	–	2	–	2	3	3	3
CO2	3	3	2	3	2	1	–	–	2	–	2	3	3	3
CO3	3	3	3	3	2	1	–	–	2	–	2	3	3	3
CO4	3	3	2	3	2	1	–	–	2	–	2	3	3	3

Correlation Level 1: Slight 2: Moderate 3: High

4th Semester Sessional

Process Metallurgy Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Laboratory Course	Course Code:	MS2544

Course Objectives:

1. To train students in standard testing methods for evaluating coal, coke, and iron ore properties.
2. To provide practical knowledge of iron ore pelletization and sintering, including performance evaluation.
3. To demonstrate key steelmaking operations such as charge calculations, slag analysis, and furnace control.
4. To introduce hydrometallurgical and electrometallurgical techniques for copper extraction from low-grade ores.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the physical and chemical characteristics of coal, coke, and iron ore through standard laboratory tests.

CO2: Demonstrate the processes of pelletization and sintering of iron ore and evaluate the mechanical properties and performance of the products.

CO3: Apply and perform key operations in steelmaking, including charge calculations, slag characterization, and furnace parameters.

CO4: Apply extractive and refining techniques to recover copper from low-grade ores using hydrometallurgical and electrometallurgical methods.

List of experiments:

(Minimum 08 experiments)

1. Proximate analysis of coal and coke.
2. To determine calorific value of coal and coke using bomb calorimeter.
3. To determine bulk and true density of coal sample.
4. To determine shatter and abrasion indices of coal and coke.
5. To determine Reactivity of coke

6. To determine Reactivity of coke Reducibility of iron ore.
7. Evaluation of swelling index of pellet.
8. Palletization of iron ore fines, the firing of pellet, and measurement of their crushing strengths
9. Preparation of fluxed, super fluxed and acid sinter
10. Flow sheets for different steel making processes
11. Charge calculation in steel making
12. LD Slag characterization using XRD.
13. Oxidation of sponge iron.
14. Decomposition kinetics of Dolomite.
15. Study of different parameters of EAF
16. Extraction of Cu from a low-grade ore through Hydrometallurgical route
17. Extraction of Cu from a low-grade ore through Electrometallurgical route
18. Electro-refining of Cu from an impure anode

CO-PO-PSO Mapping

CO	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO10**	**PO11**	**PSO 1**	**PSO 2**	**PSO 3**
CO1	3	3	2	3	2	1	–	–	2	–	2	3	3	2
CO2	3	3	3	3	2	2	–	–	2	–	2	3	3	3
CO3	3	3	3	3	3	2	1	–	2	–	2	3	3	3
CO4	3	3	3	3	3	2	1	–	2	–	3	3	3	3

Correlation Level 1: Slight 2: Moderate 3: High

4th Semester Sessional

Materials Processing Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Laboratory Course	Course Code:	MS2546

Course Objectives:

1. To provide hands-on experience with various welding techniques and examine weld quality and heat-affected zones.
2. To evaluate moulding and core materials through standard tests and understand their influence on casting quality.
3. To perform melting and casting of ferrous and non-ferrous alloys and identify common casting defects.
4. To introduce mechanical working and powder metallurgy methods, focusing on key parameters in forming and sintering.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Demonstrate practical knowledge of various welding techniques and analyze the weld quality and heat-affected zones through visual and microstructural examination.

CO2: Evaluate the properties of moulding and core materials by conducting standard sand tests and understand the role of moulding techniques in casting quality.

CO3: Perform melting and casting operations for ferrous and non-ferrous alloys, and analyze casting defects to improve process quality.

CO4: Apply mechanical working and powder metallurgy techniques to process materials and evaluate fundamental parameters in forming and sintering.

Suggested Experiments:

(Minimum 08 experiments)

1. Gas welding, manual metal arc welding, submerged arc, electroslag welding, TIG, MIG.
2. Examination of the various zones of the arc in arc welding process.
3. Effect of increasing amperage on the quality of weld bead.
4. Microstructural investigation of the welded and heat affected zones.
5. Brazing of steel/ cast iron and observation of the relevant joined microstructures.

6. Moulding methods
7. Preparation of standard samples for common sand testing
8. Measurement of green compression strength, hardness, permeability and moisture content in the moulding sand.
9. Determination of compressive strength in sodium silicate/CO_2 mould as a function of gassing time and pressure.
10. Determination of the tensile strength of oil/resin bonded core sand.
11. Melting practice for a few ferrous and non-ferrous alloys, casting defect analysis.
12. Experiments on mechanical working processes like rolling, forging, extrusion, wire drawing, forming. Measurement of fundamental parameters in metal forming, calibration of load cells, sheet metal forming, measurement of flow curves, bulk forming.
13. Mixing ceramic / metal powders, making pellets, sintering.

Text Books:

1. Principles of Metal Casting by R. W. Haine, C. Loper, and P. C. Rosenthal. McGraw Hill Education, 2001.
2. Mechanical Metallurgy by George E. Dieter, McGraw Hill.
3. Welding by Little, TMH.
4. Powder Metallurgy- Science, Technology and Materials by Anish Upadhyaya and G.S. Upadhyaya, University Press- IIM.
5. Powder Metallurgy: Science, Technology and Applications by Angelo P.C., Ravisankar B. and Subramanian R.

CO-PO-PSO Mapping

CO	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO10**	**PO11**	**PSO 1**	**PSO 2**	**PSO 3**
CO1	3	3	2	3	3	1	2	2	2	1	2	3	3	3
CO2	3	3	2	3	2	1	–	–	2	–	2	3	3	2
CO3	3	3	3	3	3	1	–	2	2	1	2	3	3	3
CO4	3	3	2	3	3	1	–	2	2	1	2	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

Advanced Digital Manufacturing Lab			
Hours/Week L-T-P :	0-0-3	Credits:	1.5
Course Type :	Laboratory Course	Course Code:	MS2548

Course Objective:

1. To analyze the different software to solve manufacturing problems
2. To learn the codes of CNC
3. To Perform experiments in EDM,ECM and 3D printing.

Course Outcomes:

Upon completion of this course, the students will be able to:

CO1: Use the software like Auto MOD, PROOD, SLAM-II to solve real world problems
CO2: Write programs for CNC machining
CO3: Prepare model using 3D printing
CO4: Analyze MRR, TWR and other parameters in unconventional machining processes

List of experiments:

1. To learn the application of the following software to manufacturing problems: Auto MOD Software, PROMOD, SLAM-II, CAFIMS, Flexsim
2. Introduction to CNC machines
3. Study of different codes for different operations
4. Write a program for CNC to obtain a specified job
5. Experimental Study of MRR on EDM
6. Experimental Study of TWR on EDM
7. Experimental Study of Surface Roughness on EDM
8. Experimental Study on ECM
9. Experimental Study on 3D Printing

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	3	1	1	2	1	1	1	3	2	2
CO2	3	2	1	2	3	1	1	2	3	2	1	2	2	2
CO3	3	2	2	2	3	2	1	2	2	1	1	2	2	1
CO4	3	2	1	2	3	2	1	1	2	2	1	2	2	1

Correlation Level 1: Slight 2: Moderate 3: High

5th Semester

5th Semester PC8

Phase Transformation and Heat Treatment			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS3141

Prerequisite:

Metallurgical Thermodynamics and Kinetics**,** Material Science and Engineering

Course Objectives:

1. To introduce the principles of thermodynamics and kinetics governing phase transformations in materials.
2. To develop the ability to interpret binary and ternary phase diagrams for predicting microstructural evolution.
3. To study the transformation mechanisms in steels and cast irons using the iron-carbon phase diagram.
4. To familiarize students with heat treatment techniques for tailoring mechanical properties of metallic alloys.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the thermodynamics and kinetics of phase transformations, including diffusion, nucleation, and growth mechanisms in solid and liquid states.

CO2: Interpret and utilize binary and ternary phase diagrams to predict microstructural evolution during solidification and solid-state transformations.

CO3: Analyze the iron-carbon system and describe transformation behaviors in steels and cast irons, including pearlitic, bainitic, and martensitic transformations.

CO4: Apply heat treatment processes such as annealing, hardening, tempering, and surface treatments to engineer desired mechanical properties in ferrous and non-ferrous alloys.

Module 1: **(12 Hours)**

Introduction: Thermodynamics of phase equilibrium and phase changes; Definition, utility, order and classification of phase transformations.

Diffusion: Definition of Fick's law on steady and non-steady state diffusion and their solutions; Mechanism of diffusion in solids; Chemical diffusion and Darken's equation; Kirkindall effect; Effect of pressure and temperature on diffusivity.

Nucleation and growth: Formation of nucleus; Homogeneous and Heterogeneous nucleation; Mechanism and kinetics of thermally activated growth; Interface and diffusion control growth regimes.

Phase equilibrium and phase diagrams: Important phase changes in unary and binary systems; Types and interpretation of phase diagram; Utility of phase diagrams, Lever rule; Important phase diagrams in metallic and ceramic systems; Free energy composition diagrams; Ternary phase diagrams; Isomorphous and eutectic systems.

Module 2: **(10 Hours)**

Liquid-solid transformation: Solidification, nucleation and growth mechanisms and kinetics; Alloy solidification – cellular and dendritic morphology; Eutectic and peritectic solidification. Application of solidification.

Solid state diffusive transformation: Classification of solid-solid transformations; Nucleation in solids; Precipitate growth; Age hardening; Spinodal decomposition; Precipitate coarsening. Order-disorder change, polymorphic change. Recrystallization, grain growth. Eutectoid transformation. Application of solid state precipitation. Pearlitic and bainitic transformations in steel; Martensite and martensitic changes in ferrous materials.

Module 3: **(7 Hours)**

Iron-carbon alloy system: Iron-cementite and iron-graphite phase diagrams, Cooling of hypo-eutectoid, eutectoid and hyper-eutectoid steels, hypo-eutectic, eutectic and hyper-eutectic cast irons, nucleation and growth of pearlite.

Module 4: **(8 Hours)**

Heat treatment of steels: TTT and CCT diagrams, conventional heat treatment processes – annealing, normalizing, hardening and tempering. Hardenability, role of alloying elements in steels. Surface hardening and chemical treatment in steels; Thermo-mechanical treatment of steels; High temperature and low temperature Thermo-mechanical treatment. Heat treatment of some Cu, Al and Ti based alloys.

Text Books:

1. Phase Transformation in Metals and Alloys by D. A. Porter and K. Easterling, CRC Press.
2. Phase Transformation in Materials by R. C. Sharma, CBS.
3. Solid State Phase Transformations by V. Raghavan, PHI

4. Heat Treatment: Principles and Techniques by Ashok Rajan, T.V. Sharma, C.P. Sharma, PHI.
5. Introduction to Physical Metallurgy, Sidney H. Avner, McGraw Hill.

Reference Books:

1. Steel and its Heat treatment by K.E. Thelning, Butterworth
2. Principles of Heat Treatment of Steels, ASM
3. Physical Metallurgy Principles by R. E. Reed-Hill, East West Press
4. Theory of Transformations in Metals and Alloys by J.W. Christian, Pergamon Press.
5. Physical Metallurgy: Principles and Practice, V. Raghavan, PHI.
6. Physical Metallurgy for Engineers, D. S. Clark and W. R. Varney, CBS Publications, New Delhi, 1st Edition, 1979
7. The Physical Metallurgy of Steels, by W.C. Leslie, McGraw-Hill International.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	-	2	-	-	-	-	-	-	2	3	2	-
CO2	3	3	2	2	2	-	-	-	1	-	2	3	3	2
CO3	3	3	2	2	-	-	-	-	1	-	2	3	3	2
CO4	3	2	3	2	3	1	1	1	2	2	2	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

5th Semester PC9

Deformation Behaviour of Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS3143

Prerequisite:

Mechanics of Materials

Course Objectives:

1. To introduce the fundamentals of stress, strain, and elastic behaviour in materials.
2. To explain the mechanisms of plastic deformation and the influence of dislocations and strengthening techniques.
3. To analyze fracture behaviour and material response under varying mechanical and thermal conditions.
4. To provide an understanding of creep, fatigue, and fracture mechanics in assessing long-term material performance.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the concepts of stress and strain using continuum mechanics and describe elastic behaviour in isotropic and anisotropic materials.

CO2: Analyze the mechanisms of plastic deformation in single crystals and polycrystalline materials, including the role of dislocations and strengthening methods.

CO3: Interpret the micro-mechanisms of fracture and evaluate material response under tension, including the effects of strain rate and temperature.

CO4: Explain the fundamentals of creep, fatigue, and fracture mechanics and their role in long-term material performance.

Module 1: **(10 Hours)**

Introduction: Elastic, plastic and visco-elastic deformation.

Continuum mechanics: Concepts of stress and strain in 3D stress and strain tensor, principal stresses and strains and principal axes, mean stress, stress deviator, maximum shear, equilibrium of stresses, equations of compatibility.

Elastic behaviour of materials: Constitutive equations in elasticity for isotropic and anisotropic materials, strain energy, elastic stiffness and compliance tensor, effect of crystal structure on elastic constants.

Plastic response of materials: a continuum approach: classification of stress-strain curves, yield criteria.

Plastic deformation of single crystals: Concepts of crystal geometry, lattice defects, deformation by slip, slip in a perfect lattice, slip by dislocation movement, critical resolved shear stress, deformation by twinning, stacking faults, deformation band and kink band, strain hardening of single crystal; stress-strain curves of fcc, bcc and hcp materials.

Module 2: **(9 Hours)**

Dislocation Theory: Elements of dislocation theory, movement of dislocation, elastic properties of dislocation, intersection of dislocation, dislocation reactions in different crystal structures, origin and multiplication of dislocations, dislocation pile-ups.

Module 3: **(9 Hours)**

Plastic deformation of polycrystalline materials: Role of grain boundaries in deformation, strengthening by grain boundaries, yield point phenomenon, strain ageing, strengthening by solutes, precipitates, dispersoids and fibres.

Module 4: **(10 Hours)**

Fracture: Types of fracture in metals, theoretical cohesive strength of metals, Griffth theory of brittle fracture, fracture of single crystals, metallographic aspects of fracture, dislocation theories of brittle fracture, ductile fracture.

Tension test: Engineering& true stress-strain curves, evaluation of tensile properties, Tensile instability, Effect of strain-rate & temperature on flow properties.

Introduction to creep, fatigue and fracture mechanics.

Text Books:

1. Mechanical Metallurgy by G. E. Dieter, McGraw-Hill.
2. Mechanical Behaviour of Materials by M. A. Meyers and K.K. Chawla, Cambridge University Press.
3. Mechanical Behavior of Materials, Thomas H. Courtney, McGraw Hill, New York, 2nd Edition, 2000. (ISBN0-07-028594-2).

Reference Books:

1. Norman E. Dowling, Mechanical Behavior of Materials, Prentice-Hall, Upper Saddle River, New Jersey, 2nd Edition, 1999. (ISBN0-13-905720-X).
2. Derek Hull and D.J. Bacon: Introduction to Dislocations, Pergamon Press, 2008.
3. Deformation and Fracture Mechanics of Engineering Materials by R.W. Hertzberg, John Wiley.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	1	–	1	–	–	–	–	–	2	3	2	1
CO2	3	3	2	2	2	–	–	–	–	–	2	3	3	2
CO3	3	2	2	2	1	–	–	–	–	–	3	3	3	2
CO4	3	3	2	2	2	2	1	–	–	–	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

5th Semester PC10

Characterization of Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS3145

Course Objectives:

1. To introduce X-ray diffraction methods for analyzing crystal structures and material stresses.
2. To develop skills in optical microscopy for microstructural characterization of materials.
3. To explain electron microscopy techniques for surface and internal structural analysis.
4. To familiarize students with spectroscopic and thermal analysis for assessing composition and thermal properties of materials.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Apply X-ray diffraction techniques to analyze crystal structures, determine lattice parameters, and assess residual stresses in materials.

CO2: Utilize optical microscopy methods to evaluate microstructural features, including phase contrast, resolution, and sample preparation techniques.

CO3: Analyze material surfaces and internal structures using scanning and transmission electron microscopy, including electron diffraction and imaging techniques.

CO4: Explain and apply spectroscopic and thermal analysis techniques to evaluate the chemical composition and thermal behavior of materials.

Module 1: (10 Hours)

Structural Characterization: X ray diffraction Symmetry, Lattice, points groups, Bravais lattices, crystal systems, X-ray generation, Bragg Law, factors influencing intensity, Techniques, Indexing, precise lattice parameter determination, residual stress measurement.

Module 2: (9 Hours)

Microstructural Characterization: Optical Microscopy: Introduction, Contrast, Magnification, Resolution, Numerical aperture, Coherent and incoherent waves, Rayleigh and Abbe's criterion for resolution, Different lens defects, Depth of field, Depth of focus, Bright field microscopy, Dark field microscopy, Phase contrast microscopy, Sample preparation for metallography.

Module 3: (8 Hours)

Scanning electron microscopy: Electron Specimen interaction, Magnification, Resolution, Depth of field, Construction and principles, Contrast, sample preparation, Different detectors, contrast and image quality.

Module 4: **(11 Hours)**

Transmission Electron Microscopy: Construction and principles, sample preparation, Different modes, lens defects and it correction, principles of Diffraction, Ewald spheres, Indexing, Kikuchi lines, Imaging, application on materials.

Chemical Characterization: Basic principles of spectroscopic techniques: EDS, WDS, XPS, EELS.

Thermal Analysis: Principles of DTA, TGA and DSC.

Text Books:

1. Fundamentals of Light Microscopy and Electronic Imaging: Douglas B. Murphy and Michael Davidson, Wiley-Blackwell, 2012.
2. Scanning Electron Microscopy and X-Ray Microanalysis: A Text for Biologists, Materials Scientists, and Geologists by Joseph Goldstein and Dale E. Newbury, Springer 2011.
3. Elements of X-ray diffraction: B.D. Cullity, Pearson Education 2014,
4. Electron microscopy and analysis: P. J. Goodhew, J. Humphreys, R. Beanland, 3rd edition, CRC Press 2000.
5. Materials Characterization Techniques, S Zhang, L. Li and Ashok Kumar, CRC Press,

Reference Books:

1. David B. Williams, C. Barry Carter, Transmission Electron Microscopy, Textbook for Materials Science, Springer, 2009, 2nd Edition.
2. An Introduction to Material Characterization, Khangaonkar P R, Penram Intl. Publishing (India) Pvt. Ltd, Mumbai, 2010.
3. ASM Handbook, Vol.10, Materials Characterization, ASM International, USA, 1998.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	3	3	–	–	–	1	–	2	3	3	2
CO2	3	2	2	2	3	–	–	–	1	–	2	3	3	2
CO3	3	3	2	3	3	–	–	–	1	–	2	3	3	3
CO4	3	3	2	2	3	1	1	–	1	–	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

5th Semester PE-I

Additive Manufacturing			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - I	Course Code:	MS3141

Course Objectives:

1. To introduce the principles, materials, and equipment of Additive Manufacturing (AM) within the Industry 4.0 framework.
2. To analyze various AM technologies, their working principles, advantages, and limitations.
3. To explore the applications of AM across diverse industries and assess its practical impact.
4. To study recent trends, standards, and advancements in AM technologies and processes.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Describe the fundamentals of Additive Manufacturing (AM), including its principles, material and equipment selection, technologies, innovations, and applications in the context of Industry 4.0.

CO2: Analyze various AM technologies such as VAT photopolymerization, material jetting, material extrusion, binder jetting, sheet lamination, powder bed fusion, and directed energy deposition, assessing their principles, advantages, limitations, and applications.

CO3: Explore emerging applications of AM in sectors including medical, aerospace, defense, automotive, construction, jewelry, and rapid tooling, evaluating their impact and potential.

CO4: Evaluate recent developments and trends in AM, understanding its compliance with ASTM/ISO standards, process parameters, advantages, limitations, and advancements in the field.

Module 1: **(12 Hours)**

Fundamentals, principles, selection for material and equipment, technologies, innovations, and applications of additive manufacturing (AM)/ 3D printing. Products based on industry 4.0 environment.

Additive Manufacturing technologies such as VAT photo-polymerization, material jetting, material extrusion, binder jetting, sheet lamination, powder bed fusion, and directed energy deposition.

Module 2: **(6 Hours)**

Emerging applications in sectors such as medical, aerospace, defence, Automobile, construction, jewellery, and rapid tooling.

Module 3: **(10 Hours)**

Recent developments and trends in AM, and its compliance to the ASTM/ISO standards basics of AM, its various technologies, process parameters, advantages, limitations, and recent advances.

Module 4: **(8 Hours)**

AM systems, materials, postprocessing, safety considerations and applications in the era of industry 4.0

Text Books:

1. Additive Manufacturing: Principles, Technologies and Application by C.P. Paul, A.N. Jinoop, McGraw Hill.
2. Additive Manufacturing Technologies by S. Shiva, Anuj K. Shukla, Wiley.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	-	2	2	-	-	2	2	2	2	2	3
CO2	3	3	3	2	3	2	-	-	1	-	2	3	3	3
CO3	2	2	3	-	3	2	1	1	2	2	2	2	2	3
CO4	3	2	2	2	3	2	1	-	1	2	3	2	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

5th Semester PE-I

Physics of Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - I	Course Code:	MS3143

Course Objectives:

1. To introduce the fundamental thermal, electrical, and electronic properties of materials.
2. To apply principles of statistical mechanics and quantum theory to describe particle behaviour in materials.
3. To analyze electronic structure and energy band formation using theoretical models.
4. To explore advanced material phenomena such as superconductivity, optoelectronics, and nanoscale physics.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the fundamental properties of materials, including thermal expansion, electrical conductivity, and the behaviour of free electron gases.

CO2: Apply statistical mechanics and quantum theory to describe the behaviour of classical and quantum particles, utilizing Maxwell-Boltzmann and Fermi-Dirac statistics.

CO3: Analyze the electronic structure of materials, including the concepts of density of states, Fermi energy, and the formation of energy bands through models like the free electron and tight binding approximations.

CO4: Explore advanced material properties, such as superconductivity, optoelectronic behaviours, and the physics of nanoscale materials, integrating concepts like Bose-Einstein statistics and the Meissner effect.

Module 1: **(10 Hours)**

Overview of properties of materials.

Thermal expansion.

Electrical Conductivity, Measuring electrical conductivity.

Free electron gas, ideal gas.

Free electron theory of metals, Wiedemann-Franz law, Drude model, Successes and Limitations of Drude model, Source of limitations of Drude model.

Module 2: **(10 Hours)**

Large systems and Statistical Mechanics, Maxwell Boltzmann statistics.

Classical Particles, Quantum particles, History of quantum mechanics, Drude-Sommerfeld model.

Fermi-Dirac Statistics, Features of Fermi-Dirac Distributions, comparison with Maxwell-Boltzmann statistics,

Module 3: **(10 Hours)**

Anisotropy and Periodic potential, Confinement and Quantization, Density of states.

Fermi Energy, Fermi Surface, Fermi Temperature, Electronic contribution to Specific Heat at Constant Volume.

Reciprocal space.

Wigner Seitz Cells, Brillouin Zones, Allowed Energy Levels, and the Origin of Bands.

Calculating allowed and forbidden energy levels, free electron approximation, tight binding approximation.

Module 4: **(6 Hours)**

Electron compounds, Semiconductors, dielectric properties, Optoelectronic properties, magnetic properties, phonons.

Superconductivity, Bose-Einstein statistics, Meissner effect, BCS theory, Physics of nanoscale materials.

Text Books:

1. Physics of Materials: Essential Concepts of Solid-State Physics. Prathap Haridoss, Wiley, 2015.
2. Kittel's Introduction to Solid State Physics by Charles Kittel, Wiley India Edition.
3. Introduction to Solids by Leonid V. Azároff, McGraw Hill.

Reference Books:

1. Solid State Physics, Ashcroft and Mermin, Cengage 2003

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	-	2	-	-	-	1	-	2	3	2	2
CO2	3	3	2	-	2	-	-	-	-	-	2	3	3	2
CO3	3	3	2	-	2	-	-	-	1	-	2	3	3	2
CO4	3	3	2	1	3	1	1	-	1	-	3	3	3	3

Correlation Level	1: Slight	2: Moderate	3: High

5th Semester PE-I

Ceramics			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - I	Course Code:	MS3145

Course Objectives:

1. To learn about the crystal structures, defects, and phase equilibria of ceramic materials.
2. To study the mechanical, thermal, optical, electrical, and magnetic properties of ceramics.
3. To explore various types of ceramics and their industrial applications.
4. To learn ceramic fabrication and processing techniques for producing functional ceramic products.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the fundamental structures and properties of ceramics, including crystal structures, imperfections, and phase equilibria.

CO2: Analyze the mechanical, thermal, optical, electrical, and magnetic properties of ceramic materials, and understand their implications for various applications.

CO3: Explore the diverse types of ceramics, such as glasses, refractories, abrasives, and advanced ceramics, and evaluate their specific applications in industries like MEMS, optical fibers, and ceramic ball bearings.

CO4: Apply fabrication and processing techniques for ceramics, including sintering, slip casting, and tape casting, to produce and characterize ceramic products.

Module 1: (10 Hours)

Introduction, Ceramic Processes and Products.

CERAMIC STRUCTURES

Structure of Crystals; AX-Type Crystal Structures - Rock Salt Structure, Cesium Chloride Structure, Zinc Blende Structure, A_mX_p-Type Crystal Structures, $A_mB_nX_p$-Type Crystal Structures, Crystal Structures from the Close Packing of Anions, Ceramic Density Computations.

Silicate Ceramics: Silica, Silica Glasses, the Silicates- Simple Silicates, Layered Silicates

Carbon: Diamond, Graphite, Fullerenes.

Imperfections in Ceramics: Atomic Point Defects, Impurities in Ceramics, Surfaces, Interfaces, and Grain Boundaries.

Diffusion in Ionic Materials

Ceramic Phase Equilibrium Diagrams: Al_2O_3–Cr_2O_3 System, MgO–Al_2O_3 System, ZrO_2 – CaO System, SiO_2–Al_2O_3 System.

Phase Transformation.

Module 2: (10 Hours)

PROPERTIES OF CERAMICS

Mechanical Properties: Brittle Fracture of Ceramics, Fractography of Ceramics, Stress–Strain Behaviour - Flexural Strength; Mechanism of Plastic Deformation - Crystalline Ceramics, Non-crystalline Ceramics; Viscous Flow and Creep; Elasticity; Anelasticity and Strength; Thermal and Compositional Stresses.

Thermal Properties; Optical Properties; Electrical Conductivity; Dielectric Properties; Magnetic Properties.

Module 3: (8 Hours)

TYPES AND APPLICATIONS OF CERAMICS

Glasses, Glass–Ceramics, Properties and Applications of Glass–Ceramics; Clay Products; Refractories: Fireclay Refractories, Silica Refractories, Basic Refractories, Special Refractories; Abrasives; Cements; Advanced Ceramics: Microelectromechanical Systems (MEMS), Optical Fibers, Ceramic Ball Bearings.

Module 4: (9 Hours)

FABRICATION AND PROCESSING OF CERAMICS

Fabrication and Processing of Glasses and Glass–Ceramics: Glass Properties, Glass Forming, Heat Treating Glasses: Annealing, Glass Tempering, Fabrication and Heat Treating of Glass–Ceramics. Reactions with and between Solids, Grain Growth, Sintering and Vitrification, Microstructure of Ceramics.

Fabrication and Processing of Clay Products: Characteristics of Clay, Compositions of Clay Products, Hydroplastic Forming, Slip Casting, Drying and Firing.

Powder Pressing; Sintering, Tape Casting.

Text Books:

1. Introduction to Ceramics by W. David Kingery, H.K. Bowen, Donald R. Uhlmann, Wiley.
2. Materials Science& Engineering- An Introduction, W. D. Callister, John Wiley & Sons.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO11	PSO 1	PSO 2	PSO 3

CO1	3	2	2	-	2	-	-	-	1	-	2	3	2	2
CO2	3	3	2	2	2	2	-	-	1	-	2	3	3	3
CO3	2	2	3	-	2	2	1	1	2	1	2	2	2	3
CO4	3	2	3	2	3	-	-	1	1	1	3	2	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

5th Semester PE-I

Surface Engineering			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - I	Course Code:	MS3147

Course Objectives:

1. To introduce surface degradation mechanisms and failure modes in engineering materials.
2. To study various surface engineering techniques, including their advantages, limitations, and applications.
3. To compare surface modification and coating methods based on performance, cost, and efficiency.
4. To develop problem-solving skills through case studies in surface engineering applications.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Classify and relate various surface degradation and surface-initiated failure mechanisms of engineering solids occurring under different service conditions.

CO2: Analyze the importance, relative advantages, limitations, and overall scope of application of various surface engineering methods, including conventional and advanced techniques.

CO3: Compare and contrast different surface modification and coating technologies from various perspectives of applicability, economy, efficiency, and scopes of further improvement.

CO4: Analyze real-life surface failure problems (case studies) and prescribe the correct surface engineering solution, integrating theoretical knowledge with practical applications.

Module 1: (10 Hours)

Need for engineered surface, definition and principles; Conventional surface hardening methods; Methods involving no change in the chemical composition of the surface; Methods involving change in chemical composition of the surface.

Module 2: (10 Hours)

Application of advanced techniques such as ion and electron beam towards creating new engineered surface

Controlled high quality surface modification by techniques such as CVD, PVD. Plasma,

laser, ion bombardment

Module 3: **(8 Hours)**

Effect of process variables and structure - property correlations

Thermo - chemical, thermo - mechanical and thermal processes

Module 4: **(8 Hours)**

Treatments for industrial components

Case studies

Text Books:

1. Introduction to Surface Engineering, P. A. Dearnley, Cambridge University Press, 2017

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	2	2	-	-	1	-	2	3	2	2
CO2	3	2	2	2	3	2	-	-	1	-	2	3	3	3
CO3	3	2	3	2	3	2	1	1	1	1	2	3	3	3
CO4	3	3	3	3	3	2	1	1	2	2	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

Business Management			
Hours/Week L-T-P :	3-0-0	Credits:	2
Course Type :	HS	Course Code:	BH3401

Prerequisites: Basic understanding of organizational structure, business fundamentals, and communication skills.

Course Objectives:

1. To understand fundamental management principles, roles, functions, and modern approaches.
2. To develop financial literacy by exploring sources of finance, capital structure etc.
3. To equip students with essential human resource management knowledge, focusing on recruitment etc.
4. To impart a comprehensive understanding of marketing concepts, strategies, and tools

Course Outcomes:

1. Comparing and contrasting efficient functional models of business management by integrating the three core areas such as Finance, Human Resource and Marketing Management.
2. Executing the Management principles in all the functional areas of business.
3. Correlating the interrelations and interdependence of the areas of Management in a business organisation.
4. Assessing the functional and managerial practices in business organisations.

MODULE-1: Management Principles **(8 Hours)**

Management Concepts, Nature and Functions, Management Process and Roles of Managers, Levels of Management and Managerial Skills, Theories of Management – Contributions of F.W.Taylor, Henry Fayol, Elton Mayo, Line and Staff Relationship, Centralisation and Decentralisation, Delegation of Authority , Management thoughts in Modern Trend –Systems Approach

MODULE-2: Financial Management **(8 Hours)**

Concept, Financial function and Role of Financial Managers, Instruments of raising short-term and long-term funds, Capital Structure, Techniques of Project Appraisal, Components of Working Capital, Operating Cycle, Factors affecting requirement of Working Capital.

MODULE-3: Human Resource Management **(7 Hours)**

Nature and Scope of Human Resource Management, Manpower Planning, Recruitment and Selection Methods, Performance Appraisal, Need, Objectives, Modern methods of Appraisals: 720 degree, MBO, Assessment Centre Method, Talent Acquisition, Training Need Analysis, Career Planning, Organisational Citizenship Behaviour.

MODULE- 4: Marketing Management **(7 Hours)**

Concept, Nature, Scope and Importance, Marketing Mix and 7P's of Marketing, Segmentation, Targeting, Positioning, Factors influencing consumer decision-making, e-marketing and Green Marketing

Reference Books:

1- Modern Business Organisation and Management, S.A. Sherlekar, Himalaya Publishing House, 2016.
2- Essentials of Management, Stephen P. Robbins, 6th Edition, Pearson, 2010.
3- Financial Management, Sheeba Kapil, 1st Edition, Pearson, 2013.
4- Human Resource Management Text and Cases, K. Aswathappa, 10th Edition, TMH, 2023
5- Marketing Management, Rajan Saxena, 6th Edition, TMH publishing house, 2022.
6- Principles of Management, Dipak Kumar Bhattacharyya, 1st Edition, Pearson, 2011
7- Mgmt (Principles of Management), Willium& Tripathy, 1st Edition, Cengage Learning, 2016

CO-PO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	3	1	1	1	2	2	1	3	2	2
CO2	3	3	3	2	3	0	0	0	2	2	1	3	3	2
CO3	3	2	3	3	3	1	1	1	3	3	2	3	3	3
CO4	3	2	3	3	3	1	1	0	3	3	2	3	3	3

Correlation Level 1: Slight 2: Moderate 3: High

ENTREPRENEURSHIP DEVELOPMENT			
Hours/Week L-T-P :	3-0-0	Credits:	2
Course Type :	HS	Course Code:	BH3103

Prerequisites: Basic understanding of economics, business studies, and fundamental financial concepts.

Course Objectives:

1. To introduce students to the foundational concepts of entrepreneurship, including the functions, traits, and motivation of entrepreneurs.
2. To enable students to identify, develop, and evaluate entrepreneurial ideas by conducting feasibility studies and understanding business structures and the startup process.
3. To provide knowledge on various sources of entrepreneurial finance and equip students with basic financial analysis tools
4. To familiarize students with the entrepreneurial ecosystem, including incubators, accelerators etc.

Course Outcomes:

1. Exemplifying the business opportunities, social responsibilities and the support system for setting up an enterprise.
2. Determining stages of Entrepreneurial Process starting from idea generation, developing a business plan and operational aspects of an Enterprise.
3. Appraising the different funding options and Financial Management of an enterprise.
4. Assessing the Start-up management practices like incubation, mentorship and Government initiatives.

MODULE-1: Introduction to Entrepreneurship (8 hours)

Concept, Functions of an Entrepreneur, Entrepreneurial Process, Entrepreneurial Motivation and Barriers, Traits to be a successful Entrepreneur, Creativity and scope of Entrepreneurship in India: Types of new age business (FinTech, EdTech, Healthcare, Agripreneurship, Defence, Drone, Space, IT, Robotics, Digital Transformation, Women-Entrepreneurship, Social Entrepreneurship, Corporate Social Responsibility, Business Ethics – Role of Values in Management.

MODULE-2: Entrepreneurial Idea into Action (8 hours)

Developing a Business Idea; Opportunity, Methods and Creativity, Deciding to set up a start-up, Forms of business organisations (Sole tradership/proprietorship, Partnership, Joint-Stock Company) and MSMEs (Micro, Small and Medium enterprises), Size and Location of the enterprise, Feasibility Study: Market Survey, Techno-economic feasibility and preparing a Project Report.

MODULE-3: Entrepreneurial Finance and Funding (8 hours)

Sources of funding(Bootstrapping, Angel Investors, Venture Capital, Crowdfunding etc.) Project Investment Analysis, Break-Even Analysis, ROI Analysis, Basics of Income Statement and Balance Sheet.

MODULE- 4: Managing an Enterprise (8 hours)

The Start-up ecosystem, Business Incubators, Start-up Accelerators, Mentorship and Networking, Failure and Resilience, Risk Management, Ethical dilemmas and Exit Strategies, Start-up Policy and Initiatives of the Government.

Reference Books:

1. Entrepreneurship: Successfully Launching New Ventures, B.R. Barringer, 6th, Pearson, 2020
2. Fundamentals of Entrepreneurship and Project planning, Madhurima Lall, 1st, Sultan Chand & Sons, 2021
3. Entrepreneurial Development, S.S. Khanka, 1st Edition, S Chand and Company, 1999
4. Entrepreneurship Development and Small business enterprises, P.M. Charantimath, 3rd Edition, Pearson, 2019
5. Entrepreneurship: Theory, Process and Practice, Donald F Kuratco, 11th, Cengage, 2023
6. Entrepreneurship, Robert. D. Hisrich & Sabyasachi Sinha, 11th Edition, TMH, 2020

CO-PO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	3	1	1	1	2	2	1	3	2	2
CO2	3	3	3	2	3	0	0	0	2	2	1	3	3	2
CO3	3	2	3	3	3	1	1	1	3	3	2	3	3	3
CO4	3	2	3	3	3	1	1	0	3	3	2	3	3	3

Correlation Level	1: Slight	2: Moderate	3: High

ENVIRONMENTAL ENGINEERING			
Hours/Week L-T-P :	3-0-0	Credits:	2
Course Type :	MC	Course Code:	IP3401

PREREQUISITES: Basic Physics, Basic Chemistry

COURSE OUTCOMES
At the end of the course a student will be able to

CO1: Understand the multidisciplinary nature of environmental science and ecosystem structure and functions

CO2: Analyze various forms of environmental pollution and assess their impact using scientific parameters

CO3: Demonstrate knowledge of water and wastewater treatment processes and air pollution control technologies

CO4: Evaluate the role of environmental policies, EIA, and sustainable practices in pollution control and resource conservation

Module 1 (10 hours)

Fundamentals of Environment and Ecosystem: Multidisciplinary nature of environmental Engineering.

Study of Ecosystem: Definition, Properties, Structure and Function of an ecosystem. Food chains, food webs, Flow of Energy, Ecological Pyramids, Biogeochemical cycles, Types of ecosystems, Bioaccumulation, Bio magnification, ecosystem value, Degradation of Ecosystem.

Concept of Environment and pollution: Atmospheric chemistry, soil chemistry, water quality characteristics, DO, BOD and COD, water pollution, Marine Pollution, soil pollution, thermal pollution, nuclear hazard, Air Pollution: Air Quality, cause and effects of air pollution, Water and air quality standards, and Index, Noise pollution: Introduction, Noise standards, measurement, Ln Concept and control

Module 2 (8 hours)

Water treatment process: Pre-treatment of water, conventional process, advanced water treatment process.

Waste water treatment process: Natural Treatment, Engineering Treatment -Pre- treatment, primary and secondary waste water treatment process

Air Pollution Control: The natural self-cleansing properties of Environment, Air pollution meteorology, Atmospheric dispersion, Diffusion equation, ground level emission, plume rise, Effective stack height, Air Pollution control from stationary sources by installing Engineering devices, Flue gas desulphurisation, NOX removal.

Module 3 **(8 hours)**

Solid waste management: Source, classification, separation, storage and transportation of solid wastes, Waste minimization techniques, Benefits of waste minimization, reuse, recycle, thermal and biological treatment, secure land fill technique.

Impact of Environmental pollution and related issues: Global climate change, global warming and greenhouse gases, Acid rain, ozone layer depletion, health issues.

Module4 **(4 hours)**

Environmental Impact Assessment: EIA procedure, Preparation of an EIS From unsustainable to sustainable development, circular economy, Environmental Protection Act, Air (Prevention and Control of Pollution) Act, Water (Prevention and Control of Pollution) Act, Wildlife Protection Act.

TEXTBOOKS

1. Fundamentals of Ecology, M.C. Dash, Tata McGraw Hill, 2006.
2. Environmental Pollution Control Engineering, C.S. Rao, New Age International Publishers, 2018
3. Environmental Engineering, G. Kiely, TMH, 2007

REFERENCES

1. Environmental Engineering, H.S. Peavy, D.R. Rowe and G. Tchobanoglous, McGraw Hill.
2. Introduction to Environmental Engineering and Science, G.M. Masters, Pearson,2015
3. Integrated Solid Waste Management, G. Tchobanoglous, McGraw Hill, 2014
4. Water Supply Engineering, S.K. Garg; Khanna Publishers, 37th Edition

CO-PO-PSO MAPPING

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	3	2	1	1	1	2	3	1	1	2	1	2	2	2
CO2	3	3	2	2	2	2	3	1	1	2	1	2	2	2
CO3	3	3	3	2	2	2	3	1	2	2	2	3	3	3
CO4	2	2	2	2	1	3	3	2	2	2	2	3	3	3

Correlation Level 1: Slight 2: Moderate 3: High

INDUSTRIAL SAFETY ENGINEERING			
Hours/Week L-T-P :	3-0-0	Credits:	2
Course Type :	MC	Course Code:	IP3403

PREREQUISITES: NA

COURSE OUTCOMES

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

CO1: Apply safety principles in various work environments, especially in construction and machine operations**.**

CO2: Identify safety hazards, implement safety measures,

CO3: Analyse risks to prevent accidents and injuries.

CO4: Understand of safety protocols, policies, and the responsibilities of individuals and organizations in ensuring a safe working environment.

Module 1 (6 hours)

Safety Introduction: Need for safety. Safety and productivity. Definitions: Accident, Injury, Unsafe act, Unsafe Condition, Dangerous Occurrence, Reportable accidents. Theories of accident causation. Safety organization- objectives, types, functions, Role of management, supervisors, workmen, unions, government and voluntary agencies in safety. Safety policy. Safety Officer-responsibilities, authority. Safety committee-need, types, advantages.

Module 2 (7 hours)

Personal Protection in work environment: Personal protection in the work environment, Types of PPEs, Personal protective equipment- respiratory and non-respiratory equipment. Standards related to PPEs. Monitoring Safety Performance: Frequency rate, severity rate, incidence rate, activity rate. Housekeeping: Responsibility of management and employees. Advantages of good housekeeping. 5 s of housekeeping. Work permit system-objectives, hot work and cold work permits. Typical industrial models and methodology. Entry into confined spaces.

Module 3 (7 hours)

Safety issues in Construction: Introduction to construction industry and safety issues in construction Safety in various construction operations – Excavation and filling – Under-water works – Under-pinning & Shoring – Ladders & Scaffolds – Tunnelling – Blasting – Demolition – Confined space – Temporary Structures. Familiarization with relevant Indian Standards and the National Building Code provisions on construction safety. Relevance of ergonomics in construction safety. Ergonomics Hazards - Musculoskeletal Disorders and Cumulative Trauma Disorders.

Module4 (12 hours)

Safety Hazards in Machines and Hazard identification and analysis: Machinery safeguard-Point-of-Operation, Principle of machine guarding -types of guards and devices. Safety in turning, and grinding. Welding and Cutting-Safety Precautions of Gas welding and Arc Welding. Material Handling-Classification-safety consideration- manual and mechanical handling. Handling assessments and techniques- lifting, carrying, pulling, pushing, palletizing and stocking. Material Handling equipment-operation & maintenance.

Hazard and risk, Types of hazards –Classification of Fire, Types of Fire extinguishers, fire explosion and toxic gas release, Structure of hazard identification and risk assessment. Identification of hazards: Inventory analysis, Fire and explosion hazard rating of process plants

- The Dow Fire and Explosion Hazard Index, Preliminary hazard analysis, Hazard and Operability study (HAZOP))–methodology, criticality analysis, corrective action and follow-up. Control of Chemical Hazards, Hazardous properties of chemicals, Material Safety Data Sheets (MSDS).

TEXTBOOKS

1. R.K Jain (2000) Industrial Safety, Health and Environment management systems, Khanna Publications.
2. Paul S V (2000), Safety management System and Documentation training Programme handbook, CBS Publication.
3. Krishnan, N.V. (1997).Safety management in Industry. Jaico Publishing House, New Delhi.

REFERENCES

1. John V. Grimaldi and Rollin H. Simonds. (1989) Safety management. All India Traveller Book Seller, Delhi.
2. Ronald P. Blake. (1973). Industrial safety. Prentice Hall, New Delhi.
2. Alan Waring. (1996). Safety management system. Chapman & Hall, England.
3. Vaid, K.N., (1988). Construction safety management. National Institute of Construction Management and Research, Mumbai

CO-PO-PSO MAPPING														
COs	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PSO 1**	**PSO 2**
CO1	3	3	3	2	2	2		3					3	2
CO2	3	3	3	2				3	2				3	2
CO3	3	3	3	2				3					3	2
CO4	2	2	1	2		3		3	2	2			2	2

Correlation Level 1: Slight 2: Moderate 3: High

5th Semester (Sessional)

Heat Treatment Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Laboratory Course	Course Code:	MS3541

Course Objectives:

1. To provide hands-on experience in heat treatment processes and their impact on microstructure.
2. To study recrystallization, grain growth, and phase transformations through experiments.
3. To evaluate hardenability and transformation behaviour in steels using standard testing methods.
4. To apply surface treatment techniques to modify and enhance material properties.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Demonstrate proficiency in performing various heat treatment processes and analyze their effects on the microstructure of metals and alloys.

CO2: Investigate recrystallization, grain growth, and phase transformation kinetics through experimental observation and relate them to mechanical properties.

CO3: Evaluate hardenability and phase transformation behaviour in steels using standard tests like the Jominy end-quench test and interpret the results.

CO4: Apply surface treatment techniques such as carburizing and age hardening to modify material properties.

List of Experiments:

(Minimum 08 experiments)

1. Annealing treatment of a cold worked steel and comparison of the annealed microstructure with the cold worked structure.
2. Normalizing treatment of steel and comparison of the microstructure with annealed structure.
3. To study the quenched structures of steel — quenched in oil, water and brine solution.
4. To study the quenched and tempered structures of steel -

   (i) low temperature tempering.

   (ii) medium temperature tempering.

   (iii) high temperature tempering.

5. To study the recrystallisation behaviour of pure metal (iron/ copper).
6. To study the effect of time and temperature on grain size of a metal (grain growth) (iron/ copper).
7. To study the nucleation rate and growth rate of pearlite in eutectoid steel.
8. To study the susceptibility of a steel to harden by quenching (hardenability) by Jominy test.
9. Pack carburizing of 0.2% carbon steel and to measure the diffusion coefficient of carbon in steel.
10. To study the microstructure of tool steels, stainless steels and other high alloy steels.
11. Austempering of steels and S G cast irons.
12. To carry out age hardening of non ferrous alloys.
13. Determination of hardenability of steels.

CO-PO-PSO Mapping

CO	**PO 1**	**PO2**	**PO 3**	**PO 4**	**PO5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO10**	**PO11**	**PSO 1**	**PSO 2**	**PSO 3**
CO1	3	2	3	2	3	2	–	2	2	1	2	3	3	3
CO2	3	3	2	3	2	–	–	2	2	–	3	3	3	3
CO3	3	3	2	3	2	–	–	1	2	–	3	3	3	3
CO4	3	2	3	2	3	2	1	2	2	1	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

5th Semester (Sessional)

Computational Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Laboratory Course	Course Code:	MS3543

Prerequisites

Engineering Mathematics

Course Objectives:

1. To introduce numerical computing tools like MATLAB for solving engineering problems.
2. To implement iterative methods for finding roots of nonlinear equations.
3. To apply numerical techniques for solving linear systems, differentiation, and integration.
4. To develop computational solutions for differential equations and eigenvalue problems.

Course Outcomes:

Upon successful completion of the course, students will be able to:

CO1: Utilize MATLAB or equivalent software to implement numerical algorithms and solve engineering problems efficiently.

CO2: Apply iterative methods such as Bisection, Newton-Raphson, and Secant methods to find roots of nonlinear equations with accuracy.

CO3: Analyze and solve linear algebraic systems using methods like Gauss Elimination and perform numerical differentiation and integration.

CO4: Develop computational solutions for initial value and boundary value problems, including differential equations and eigenvalue problems, using appropriate numerical techniques.

List of Experiments

1. Basics of MATLAB or similar software/language

2. Finding solution by Numerical Methods (including graphics) for the following:

(Minimum 06 problems)

a) Bisection Method

b) Newton-Raphson Method

c) Secant Method

d) Gauss Elimination Method

e) Numerical Differentiation

f) Numerical Integration

g) Curve fitting Method

h) Initial-Value Problems (e.g. Runge-Kutta Method)

i) Boundary Value Problem (eg. Shooting Method)

j) Eigen Value Problem

CO-PO-PSO Mapping

CO	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO10**	**PO11**	**PSO 1**	**PSO 2**	**PSO 3**
CO1	3	2	2	2	3	–	–	1	2	1	3	2	3	2
CO2	3	3	2	2	3	–	–	–	1	–	3	2	3	2
CO3	3	3	2	2	3	–	–	–	1	–	3	2	3	2
CO4	3	3	3	3	3	–	–	1	2	1	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

5th Semester (Sessional)

Materials Characterization Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Laboratory Course	Course Code:	MS3545

Course Objectives:

1. To provide practical training in X-ray diffraction techniques for phase and texture analysis.
2. To develop proficiency in sample preparation for advanced electron microscopy.
3. To train students in elemental analysis using EDAX and EPMA techniques.
4. To introduce thermal analysis methods for assessing thermal stability and phase transitions in materials.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Acquire hands-on experience in operating X-ray diffraction (XRD) equipment for phase identification, crystallite size determination, and texture analysis of metallic and polymeric materials.

CO2: Develop skills in sample preparation techniques for advanced microscopy tools such as Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) to analyze microstructures accurately.

CO3: Perform elemental analysis using Energy Dispersive X-ray Analysis (EDAX) and Electron Probe Micro-Analysis (EPMA) to determine the chemical composition of various materials.

CO4: Apply thermal analysis methods like Thermogravimetric Analysis (TGA), Differential Thermal Analysis (DTA), and Differential Scanning Calorimetry (DSC) for evaluating material properties such as thermal stability and phase transitions.

List of experiments:

(Minimum 08 experiments)

1. Study of the X-Ray diffraction equipment.
2. Sample preparation for XRD analysis.
3. Study of FCC metal using XRD and identifying various phases present.
4. Determination of crystallite size in a given sample using Scherer formula.
5. Texture analysis of given rolled aluminium sample.

6. Sample preparation for SEM analysis.
7. Micro structural characterization using SEM.
8. Sample preparation for TEM analysis.
9. Micro structural characterization using TEM.
10. Elemental analysis of given sample using EDAX and EPMA.
11. Thermal Analysis: TGA, DTA, Thermal analysis of epoxy polymer using DSC technique (glass transition temperature).

Text Books:

1. Fundamentals of Light Microscopy and Electronic Imaging: Douglas B. Murphy and Michael Davidson, Wiley-Blackwell, 2012
2. Scanning Electron Microscopy and X-Ray Microanalysis: A Text for Biologists, Materials Scientists, and Geologists by Joseph Goldstein and Dale E. Newbury, Springer 2011
3. Elements of X-ray diffraction: B.D. Cullity, Pearson Education 2014, 4. Electron microscopy and analysis: P. J. Goodhew, J. Humphreys, R. Beanland, 3rd edition, CRC Press 2000.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	3	3	–	–	1	2	–	2	3	3	2
CO2	3	2	2	2	3	–	–	1	2	–	2	3	3	2
CO3	3	3	2	3	3	–	–	1	2	–	3	3	3	3
CO4	3	3	2	2	3	1	1	1	2	–	3	3	3	3

Correlation Level 1: Slight 2: Moderate 3: High

6th Semester

6th Semester PC11

Composite Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS3142

Course Objectives:

1. To introduce the classification, characteristics, and applications of composite materials.
2. To develop analytical skills using micro-mechanical models for property prediction.
3. To explore manufacturing techniques for PMCs, MMCs, and CMCs based on material and application needs.
4. To understand failure mechanisms and toughness enhancement methods in composite materials.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Classify and characterize composite materials based on matrix and reinforcement types, and analyze their structural and functional roles in various applications.

CO2: Analyze and apply micromechanical to predict the elastic and strength properties of composite materials, including the use of Halpin-Tsai equations and laminate theory.

CO3: Evaluate and select appropriate manufacturing techniques for polymer matrix composites (PMCs), metal matrix composites (MMCs), and ceramic matrix composites (CMCs), considering factors like matrix-reinforcement interface, processing conditions, and application requirements.

CO4: Assess the failure mechanisms and toughness enhancement strategies in composite materials, including crack deflection, fiber pull-out, and transformation toughening, to design durable composite structures.

Module 1: **(10 Hours)**

Introduction: definitions and classifications; natural composites; role of matrix and reinforcement; factors which determine properties; the benefits of composites. Reinforcements and the reinforcement matrix interface: natural fibers; synthetic organic fibers – aramid, polyethylene; and synthetic inorganic fibers – glass, alumina, boron, carbon, silicon based fibers; particulate and whisker reinforcements, reinforcement-matrix interface – wettability, interfacial bonding, methods for measuring bond strength.

Metal matrix composites: Introduction, important metallic matrices; metal matrix composite processing: solid state processing – diffusion bonding, powder metallurgy; liquid state processing – melt stirring, compo-casting (rheocasting), squeeze casting, liquid infiltration under gas pressure; deposition – spray co-deposition and other deposition techniques like CVD and PVD; in situ processes. Interface reactions. Properties of MMCs – physical properties; mechanical properties like elastic properties, room temperature
strength and ductility, properties at elevated temperatures, fatigue resistance. Processing, structure of multi-filamentary superconductors, properties of aluminium reinforced with silicon carbide particles.

Module 2: **(10 Hours)**

Ceramic matrix composites: Introduction; processing and structure of monolithic materials– technical ceramics, glass-ceramics. Processing of ceramics: conventional mixing and pressing – cold pressing and sintering, hot pressing, reaction bonding processes, techniques involving slurries, liquid state processing – matrix transfer moulding, liquid infiltration, sol-gel processing, vapour deposition techniques like CVD, CVI, liquid phase sintering, lanxide process and in situ processes. Processing, properties and applications of alumina matrix composites - SiC whisker reinforced, zirconia toughened alumina; Glass ceramic matrix composites; Carbon-carbon composites - porous carbon-carbon composites, dense carbon-carbon composites.

Polymer matrix composites: Introduction; polymer matrices – thermosetting, thermoplastic, rubbers. Processing of PMCs: Hand methods – hand lay-up, spray-up methods; Moulding methods – matched die moulding, bag moulding processes (autoclave moulding), resin transfer moulding, pultrusion; Filament winding; Injection moulding. Processing, properties and applications of fibre-reinforced epoxies, PEEK matrix composites, rubber matrix composites. Damping characteristics. Environmental effects in polymer matrix composites. Recycling of PMCs.

Module 3: **(10 Hours)**

Composite structures: Sandwich structures, foam core type arrangements; Honey comb structures. **Micromechanics of unidirectional composites:** micromechanics models for stiffness – longitudinal stiffness, transverse stiffness, shear modulus, Poisson's ratio. Micromechanics models for strength – longitudinal tensile strength, longitudinal compressive strength, transverse tensile strength, transverse compressive strength, in plane shear failure, thermal and moisture effects.

Short fibre composites: reasons for using short fibre composites, fibre length, fibre orientation, stress and strain distribution at fibres, critical fibre length and average fibre stress, stiffness and strength: stiffness of aligned systems, non-aligned systems and variable fibre orientation, strength of aligned systems, 2-D composites, variable fibre orientation.

Module 4: **(6 Hours)**

Toughening mechanisms in composite materials: crack bowing, crack deflection, debonding, pull-out, wake toughening, microcrack toughening, transformation toughening.

Text Books:

1. Composite Materials Science and Engineering, K.K. Chawla, Springer
2. Composite Materials: Engineering and Science, by Matthews and Rawlings, CRC Press.

Reference Books:

1. An Introduction to Composite Material, by D. Hull and T.W. Clyne, Cambridge University press.
2. Metal Matrix Composites, Thermo Mechanical Behaviour by M. Taya, and R.J. Arsenault, Pergamon Press, Oxford.
3. Fundamentals of Metal Matrix Composites by S. Suresh, A. Martensen, and A. Needleman, Butterworth, Heinemann

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	1	2	2	–	–	1	–	2	3	2	2
CO2	3	3	3	2	3	–	–	–	1	–	3	3	3	3
CO3	3	3	3	2	3	2	–	1	2	1	3	3	3	3
CO4	3	3	3	2	2	2	1	1	2	–	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester PC12

Corrosion and Degradation of Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Core	Course Code:	MS3144

Course Objectives:

1. To introduce the fundamentals, forms, and significance of corrosion in engineering materials.
2. To apply electrochemical and thermodynamic principles to understand and analyze corrosion mechanisms.
3. To identify different types of corrosion and explore their causes, effects, and prevention strategies.
4. To study corrosion testing, monitoring, and control techniques for metals, polymers, and composites.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the fundamentals of corrosion, including its definition, forms, and classification, and recognize the importance and economic impact of corrosion studies.

CO2: Apply electrochemical and thermodynamic principles to analyze corrosion mechanisms, utilizing tools such as the EMF series, Nernst equation, and Pourbaix diagrams.

CO3: Identify and characterize various forms of corrosion, including uniform, localized, galvanic, crevice, pitting, intergranular, and environmentally assisted failures, and understand their causes and prevention methods.

CO4: Evaluate corrosion measurement techniques and control methods, including exposure studies, electrochemical testing, coatings, inhibitors, and cathodic/anodic protection, and assess the degradation of polymeric and composite materials.

Module 1: **(8 Hours)**

Introduction, Definition, Forms of environmental degradation, Classification of corrosion Importance of corrosion studies and cost of corrosion.

Corrosion principles: Electrochemical aspects, Thermodynamic aspects of corrosion – Gibbs energy and electrochemical potential.

Module 2: **(10 Hours)**

Metal-Electrolyte Interface, EMF series, Nernst relationship and Pourbaix Diagram

Kinetic aspects of corrosion: Corrosion rate, Current density, Exchange current density, Mixed potential theory, Polarization and Passivation.

Module 3: **(9 Hours)**

Forms of corrosion: Uniform Corrosion, Localized Corrosion; Pitting; Crevice Corrosion, Galvanic Corrosion and Protection; Concentration Cells, Intergranular Corrosion; De-alloying, Environmentally assisted failures (SCC, Hydrogen embrittlement; corrosion fatigue), Erosion; Fretting. Experimental methods to identify corrosion susceptibility

Module 4: **(10 Hours)**

Corrosion Measurements and Corrosion Control: Exposure studies, Electrochemical work bench, DC and AC methods of testing, Polarization measurements-Corrosion rate assessment by Tafel's extrapolation method, Linear polarization resistance (LPR). Coatings, Inhibitors, Cathodic and Anodic protection.

Degradation of polymeric and composite materials and its prevention

Text Books:

1. Corrosion Engineering, Mars. G. Fontana, McGraw Hill Education, 2017
2. Electrochemical Techniques in Corrosion Science and Engineering. R.G. Kelly, J.R. Scully, D.W. Shoesmith, R.G. Buchheit, CRC Press., 2002

Reference Books:

1. Corrosion: Metal / Environment Reactions, Volume 1, L.L. Shreir, R.A. Jarman, G.T. Burstein, Butterworth-Heinemann, 1994.
2. Principles and Prevention of Corrosion, Denny A. Jones, Pearson, 1995.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	–	–	2	1	–	2	–	2	3	2	2
CO2	3	3	2	2	2	–	–	–	1	–	3	3	3	2
CO3	3	3	2	2	2	2	1	–	1	–	3	3	3	3
CO4	3	3	3	3	3	2	1	1	2	–	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester **PE-II**

Finite Element Modelling of Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - II	Course Code:	MS3242

Course Objectives:

1. To introduce fundamental variational methods such as Ritz and Galerkin for finite element formulation.
2. To develop finite element models for 1D and truss structures using direct and penalty approaches.
3. To formulate and solve 2D problems in elasticity, heat transfer, and fluid flow using FEM.
4. To apply FEM to complex 3D structures and advanced applications in thermal and fluid mechanics.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Apply fundamental variational principles such as the Ritz and Galerkin methods to derive finite element formulations for engineering problems.

CO2: Develop and implement finite element models for one-dimensional and truss structures, utilizing both direct and penalty methods, and analyze their behavior under various loading conditions.

CO3: Formulate and solve two-dimensional finite element problems, including elasticity, heat conduction, and fluid flow, using appropriate element types and numerical integration techniques.

CO4: Analyze and model complex three-dimensional structures, incorporating advanced elements like hexahedral and shell elements, and apply finite element methods to thermal and fluid mechanics applications.

Module 1: **(9 Hours)**

Introduction: Overview of the course, examination and evaluation patterns, history and basic concept of finite element method and direct FEM.

Fundamental concepts: Calculus of variation and solving differential equations, Ritz method, Galerkin method, Least squares, collocation and subdomain methods, Case studies for Ritz and Galerkin methods, Ritz FEM formulation, Galerkin FEM formulation.

Module 2: **(8 Hours)**

One-Dimensional Problems: Finite element formulation for 1-D problems, elimination method, penalty method, computer implementation and case studies.

Trusses: Introduction, fem formulation, plane trusses, three dimensional trusses, frames and case studies.

Module 3: **(9 Hours)**

Two-Dimensional Problems: Finite element formulation for 2-D problems, constant strain triangle, various elements, iso parametric, sub parametric and super parametric elements, interpolation functions, computer implementation and case studies.

Numerical Integration and 2-D problems of Elasticity: Introduction to numerical integration, two dimensional integrals, plane stress, plane strain, axisymmetric, plate bending problems.

Module 4: **(10 Hours)**

Thermal Applications: Two - dimensional heat conduction analysis, formulation of functional, element matrices and case studies.

Fluid Mechanics Applications: Stream function formulation, velocity potential formulation and torsional analysis of a prismatic bar.

Three Dimensional Problems: Finite element formulation for 3-D problems, mesh preparation, hexahedral elements, shell elements and case studies.

Text Books:

1. Seshu P., Textbook of Finite Element Analysis, PHI, 2009.
2. Reddy, J.N., Finite Element Method in Engineering, Tata McGraw Hill, 2007.
3. Zeincowicz, The Finite Element Method for Solid and Structural Mechanics, 4th Edition, Elsevier, 2007.
4. The Finite Element Method for Engineers, 4th Edition: Kenneth H. Huebner, D

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	1	2	2	-	-	-	1	-	2	3	2	1
CO2	3	3	2	3	3	-	-	1	1	1	2	3	3	2
CO3	3	3	2	3	3	1	-	1	2	1	2	3	3	3
CO4	3	3	3	3	3	2	-	2	2	2	2	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester **PE-II**

Modelling of Materials Processes			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - II	Course Code:	MS3244

Course Objectives:

1. To make the student aware of mathematical modelling and its applications.
2. To make models of metallurgical systems.
3. To make the students aware of numerical techniques and learn how to use them for solving problems using these techniques.
4. To make models of metallurgical systems, and to solve ODEs using Simulink.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Apply mathematical techniques such as the Runge-Kutta method to solve ordinary differential equations relevant to materials processing.

CO2: Utilize MATLAB programming and Simulink modelling tools to develop and simulate models of materials processing systems.

CO3: Implement molecular dynamics simulations and first-principles methods, including density functional theory, to investigate atomic-level phenomena in materials.

CO4: Employ random walk models and numerical methods to calculate eigenvalues, enhancing the understanding of stochastic processes in materials systems.

Module 1: **(8 Hours)**

Basic ideas and techniques of mathematical modelling.

Runge-Kutta method for solving ODEs.

Module 2: **(9 Hours)**

Programming using Matlab.

Developing models using Simulink.

Module 3: **(10 Hours)**

Molecular Dynamics

First-principles methods

Density functional theory

Module 4: **(9 Hours)**

Random walk

Numerical methods to calculate Eigen values

Text Books:

1. Ruben Santamaria, Molecular Dynamics, Springer
2. Richard Lesar, Introduction to Computation Materials Science, Materials Research Society and Cambridge University Press

Reference Books:

1. J. G. Lee, Computational Material Science-An Introduction, CRC Press
2. D. Marx, Ab Intito Molecular Dynamics-Basic Theory and Advanced Methods, Cambridge University Press

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	2	-	-	-	1	-	2	3	2	1
CO2	2	3	2	2	3	-	-	1	2	1	2	3	3	2
CO3	3	3	2	3	3	1	-	1	2	1	2	3	3	3
CO4	3	2	1	2	2	-	-	1	1	-	2	3	2	1

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester **PE-II**

Molecular Modelling of Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - II	Course Code:	MS3246

Course Objectives:

1. To develop an understanding on the concepts of computational material science.
2. To learn and apply the different computational methods.
3. To learn how to analyze the data from the simulations.
4. To solve problems using software packages.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Apply computational methods in materials science, including molecular dynamics and first-principles techniques, to model and simulate material behaviours at the atomic level.

CO2: Implement and utilize molecular dynamics simulations using tools like LAMMPS, performing tasks such as initialization, equilibration, and data production to analyze material properties.

CO3: Apply density functional theory (DFT) to solve Schrödinger's wave equation, employing the Kohn-Sham approach to calculate electronic structures and understand material properties.

CO4: Evaluate and interpret the limitations and extensions of DFT, including the role of exchange-correlation functions, to assess its applicability in various material modelling scenarios.

Module 1: **(9 Hours)**

Introduction: Computational materials science

Methods in computational materials science,

Molecular dynamics:

introduction potentials Solutions for Newton's equation of motion

Module 2: **(9 Hours)**

Initialization Integration equilibration

Data production,

MD exercises with LAMMPS,

First-principle methods

Module 3: **(10 Hours)**

Schrodinger's wave equation

early first principles calculations

Density functional theory:

Instruction Kohn-Sham approach

Kohn-Sham equations

Module 4: **(8 Hours)**

exchange correlation functions

Solving Kohn-Sham equations

DFT extensions and limitations

Text Books:

1. Lee, J. G, Computational materials science: an introduction, CRC press, 2016
2. Yip. S., Handbook of materials modelling, Springer Science & Business Media. USA, 2007

Reference Books:

1. Ohno, K., Esfarjani, K., & Kawazoe, Y, "Computational materials science: from ab initio to Monte Carlo methods", Springer, 2018
2. LeSar. R, "Introduction to computational materials science: fundamentals to applications", Cambridge University Press, 2013

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	3	3	1	-	-	1	-	3	3	3	3
CO2	3	2	2	3	3	-	-	1	2	1	2	3	3	2
CO3	3	3	2	3	3	1	-	-	2	-	3	3	3	3
CO4	2	3	2	2	2	1	-	1	2	1	3	3	3	2

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester **PE-II**

Computational Materials Engineering			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - II	Course Code:	MS3248

Course Objectives:

1. To apply physical modelling and finite element techniques for predicting material behaviour.
2. To use computational thermodynamics tools like CALPHAD and ThermoCalc for phase diagram analysis.
3. To perform molecular dynamics simulations to study atomic-scale material properties.
4. To implement Monte Carlo methods and data science techniques for materials analysis within the ICME framework.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Apply physical modelling techniques and finite element methods to analyze material behaviours, including the Hall-Petch relation and Arrhenius equation, for predicting material properties.

CO2: Utilize computational thermodynamics tools such as the CALPHAD approach and ThermoCalc software to calculate equilibrium phase diagrams and understand phase transformations in materials.

CO3: Conduct molecular dynamics simulations to study atomic-level interactions and predict material properties like melting points, using appropriate interatomic potentials.

CO4: Implement Monte Carlo methods and basic data science techniques, including linear regression models, to analyze material behaviours and contribute to integrated computational materials engineering (ICME) approaches.

Module 1: **(9 Hours)**

Physical modelling of material problems, models in metallurgy: Hall-Petch relation, Arrhenius relation, equations to predict M_s and β - transition temperature.

Finite element method: introduction, solving 1-D structural and heat transfer problems.

Module 2: **(8 Hours)**

Computational thermodynamics: CALPHAD approach to calculate equilibrium diagrams, introduction to ThermoCalc and calculation of binary and pseudobinary phase diagrams.

Module 3: **(8 Hours)**

Molecular Dynamics (MD) simulations: Types of MD simulations, types of potentials used in MD simulations, using MD simulations to predict melting point of pure metals.

Module 4: **(11 Hours)**

Introduction to Monte Carlo (MC) methods in material engineering, application of MC to solve integrals.

Basics of data science, linear regression models, data analytics in materials engineering.

Integrated computational materials engineering (ICME): introduction and recent trends.

Text Books:

1. Richard Lesar, Introduction to Computational Materials Science- Fundamentals to Applications, Cambridge University Press, Cambridge UK, 2013
2. June Gunn Lee, Computational Materials Science-An Introduction, CRC Press, 2015

Reference Books:

1. Ellad B. Tadmor, Ronald E. Miller, Modeling Materials (Continuum, Atomistic and Multiscale Techniques), Cambridge University Press, New York, 2011
2. Michael Heath, Scientific Computing: An introduction survey, McGraw Hill, 2002

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	3	3	1	–	–	1	–	3	3	3	2
CO2	3	3	2	2	3	1	–	–	1	–	2	3	3	3
CO3	3	3	2	3	3	1	–	–	2	–	2	3	3	3
CO4	3	3	2	3	3	1	–	1	2	1	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester **PE-III**

Alternative Routes of Iron Making			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - III	Course Code:	MS3250

Prerequisite:

Iron and Steel making

Course Objectives:

1. To impart knowledge of the thermodynamic and kinetic principles governing the reduction of iron oxides in direct reduction processes.
2. To introduce and compare various industrial direct reduction technologies with respect to their operation, efficiency, and applicability.
3. To explore the use of alternative reducing agents and assess their impact on process performance and environmental sustainability.
4. To study the utilization of direct reduced iron (DRI) in ironmaking and steelmaking, highlighting its benefits and integration challenges.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the thermodynamics and kinetics of iron oxide reduction in both coal-based and gas-based direct reduction processes, including the Boudouard reaction and rate-limiting steps.

CO2: Evaluate and compare various direct reduction processes, such as SL/RN, MIDREX, HYL, and COREX, focusing on their mechanisms, advantages, limitations, and industrial applications.

CO3: Assess the use of alternative reducing agents, including syngas, hydrogen, and plasma, in direct reduction processes, and their impact on process efficiency and environmental sustainability.

CO4: Examine the integration of direct reduction products (DRI) into ironmaking and steelmaking processes, evaluating their properties, advantages, and challenges in blast furnaces and electric arc furnaces.

Module 1: **(9 Hours)**

The need for Alternative Iron Units.

Fundamentals of Direct Reduction: Thermodynamics and Kinetics of Iron Oxide Reduction, kinetic aspects, Mechanism of Iron Oxide Reduction in Coal-based Processes, Mechanism of Iron Oxide Reduction in Gas-based Processes, Boudouard reaction, rate of Iron Oxide reduction.

Coal-based DR Processes using Rotary Kilns: Classification of DR processes, strengths and weaknesses of rotary Kiln direct Reduction, DR Processes – SL/RN, Codir, Accar, DRC, TDR, SIIL, Jindal.

Salient features of Rotary Kiln DR: Process analysis, Raw material Characteristics.

Module 2: **(9 Hours)**

Coal-based Processes using Reactors other than Rotary Kiln:

Rotary Hearth Furnace-based Processes; Inmetco Process, Fastmet Process, Comet Process, DryIron Process, IT Mk3.

Vertical Retort-based Processes; Kinglor -Metor Process

Multiple hearth Furnace-based Processes; Primus Process

Coal-based DR in Tunnel Kilns; Hoganas.

Fluidised Bed-based Processes; Cirofer Process.

Gas-based Direct Reduction:

Use of Natural Gas in Direct Reduction, Principles of Gas-based Direct Reduction, Modules in Gas-based DR plants.

Retort Processes; HYL

Fluidised Bed Processes; Fior, Finmet, High Iron Briquette Process, Circored

Shaft Furnace Processes; HYL III, HYLSA IV M, Midrex, Armco, Purofer, NSC-DR.

Module 3: **(9 Hours)**

Gas-based Direct Reduction using alternative to Natural Gas:

Gas from Coal, Coal gasification reactions

Technologies available for coal gasification; Lurgi gas generator, Winkler process, Koppers-Totzek (KT) gasifier, Texaco (GE) gasifier, Shell coal gasifier, Sasol-Lurgi process.

Cleaning and conditioning of Syngas

Shaft Furnace DR with alternative Gases; Hydrogen, Syngas coupled with HYL, use of steel plant by-product for shaft furnace DR, combination of Midrex process with Syngas, Plasmared, BL process.

Use of DRI in Ironmaking and Steelmaking: properties of DRI, Usage of DRI in Blast Furnaces, DRI as feed material in Steelmaking.

Module 4: **(9 Hours)**

Classification of Smelting Reduction Processes

Fundamentals of Smelting Reduction: Reactions and reaction mechanisms, kinetics.

Smelting Reduction Processes:

Mini Blast furnace, Corex, Finex Process, Plasmasmelt Process, Fastmelt Process, Ausmelt, Hismelt.

Processes combining Rotary hearth Furnace with Electric Ironmaking Furnace: ITMk3, Redsmelt.

Romelt Process, AISI Process, Dios Process. Hydrogen plasma Smelting Reduction.

Text Books:

1. Sponge Iron Production by Direct reduction of Iron Oxide by Amit Chatterjee, PHI.
2. Hot Metal Production by Smelting reduction of Iron Oxide by Amit Chatterjee, PHI.
3. Alternative Routes to Iron Making by A. Sarangi and B. Sarangi, PHI

Reference Books:

1. Dipak Mazumdar, A First Course in Iron and Steel Making, University Press-IIM-2015

CO-PO-PSO Mapping

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CO2	3	3	3	2	2	2	–	1	2	1	3	3	2	3
CO3	3	3	3	2	2	3	–	–	2	1	3	3	2	3
CO4	2	3	3	2	2	2	–	1	2	2	3	3	2	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester **PE-III**

Secondary Steel Making			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - III	Course Code:	MS3252

Prerequisite:

Iron and Steel making

Course Objectives:

1. To introduce the principles and techniques of secondary steelmaking for refining steel quality.
2. To explain the thermodynamics and kinetics of degassing reactions and associated processes.
3. To study the role of transport phenomena and slag-metal interactions in impurity and inclusion control.
4. To study tundish metallurgy and post-solidification treatments for producing high-quality steels.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the principles and practices of secondary steelmaking, including the role of ladle metallurgy, vacuum degassing, and inert gas stirring in refining steel composition and quality.

CO2: Analyze the thermodynamics and kinetics of degassing reactions, focusing on nitrogen absorption/desorption, and evaluate various degassing processes such as VD, VOD, VAD, DH, and RH.

CO3: Evaluate the impact of transport phenomena in ladles, including the role of slag and powders in inclusion control, and understand the processes of desulphurization, dephosphorization, and inclusion morphology modification.

CO4: Assess the significance of tundish metallurgy, including hydrodynamic performance, solidification phenomena, and post-solidification treatments like VAR and ESR, in producing high-quality alloy steels.

Module 1: **(10 Hours)**

Basic Introduction: Ironmaking, Primary steelmaking, and Secondary Steelmaking. Integrated steel plant overviews, Final products

Primary steelmaking: Basic Oxygen Furnace, Electric Arc Furnace, furnace design, lining, Raw Materials, Product details, etc.

Secondary steel making principles and practices: Objectives and techniques adopted in secondary steel making. Ladle metallurgy: Outline of inert gas stirring: CAS/CAS (OB), Ladle furnace.

Module 2: **(10 Hours)**

Degassing and Decarburization of liquid Steel: Thermodynamics of Degassing reactions, Kinetics of Desorption and Absorption of Nitrogen by liquid Steel, Vacuum Degassing Processes; Ladle degassing processes (VD, VOD, VAD), Stream degassing processes, Circulation degassing processes (DH and RH).

Transport phenomena in ladles: Role of slag and powders in inclusion control: Desulphurization, Dephosphorization. Modification of inclusion morphologies, production of ultra low carbon by RH-OB process, ultra low sulphur, ultra low phosphorus and inclusion free steels.

Module 3: **(8 Hours)**

Tundish metallurgy: Evaluation of tundish hydrodynamic performances: Solidification phenomena: Conventional, continuous and near net shape casting phenomena. Powder injection systems. Production of alloy steel through post solidification treatments (VAR, ESR);

Module 4: **(6 Hours)**

Refractories used in secondary steel making furnaces, their properties and selection criteria. Process selection in secondary steel making.

Identification, Modification, Cleanliness Assessment of steel, origin of non-metallic inclusions and its modification, Clean Steel technology.

Text Books:

1. Ghosh A., Secondary Steelmaking- principle & Applications, CRC Press.
2. Ghosh A., Principles of Secondary Steelmaking Processing and Casting of Liquid Steel, Oxford & IBH Publication.

Suggested Reference Books:

1. Ghosh Ahindra, Chatterjee A., Iron making and Steel making Theory and Practices, PHI
2. Dipak Mazumder, James W. Evans, Modeling of Steelmaking Processes, CRC Press, 2010
3. Production of steel (Theory and Practice) by Tupkary,

CO-PO-PSO Mapping

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CO3	3	3	3	3	2	2	–	–	2	–	3	3	3	3
CO4	3	2	3	2	2	2	–	1	2	1	3	3	3	3

Correlation Level	1: Slight	2: Moderate	3: High

6th Semester **PE-III**

Powder Metallurgy			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - III	Course Code:	MS3254

Course Objectives:

1. To introduce the fundamentals, advantages, and industrial applications of Powder Metallurgy.
2. To develop understanding of powder characterization techniques and their relevance to P/M processes.
3. To explore various powder compaction methods and their influence on green compact properties.
4. To study the sintering process and its role in producing functional P/M components.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the fundamentals and scope of Powder Metallurgy (P/M), including its historical development, advantages, disadvantages, and applications in various industries.

CO2: Analyze and characterize metal powders, focusing on aspects such as chemical composition, particle size, shape, density, and flow rate, to assess their suitability for different P/M processes.

CO3: Apply various compaction techniques to metal powders, including die compaction, isostatic pressing, and continuous compaction, and understand their effects on the properties of the resulting green compacts.

CO4: Evaluate the sintering process, including its stages, mechanisms, and the impact of process variables, and understand the production of various materials such as porous bearings, sintered friction materials, and cermets.

Module 1: **(10 Hours)**

Scope of Powder Metallurgy: Introduction, historical development, advantages disadvantages and applications of P/M, characteristics of powders, Methods of powder production (mechanical, physical, chemical and electro chemical methods

Module 2: **(10 Hours)**

Compaction of Metal Powders: Methods of conditioning, Different die-compaction techniques, Isostatic pressing with advantages, limitation applications, Outline on continuous

compaction. Sintering and Explain its various stages, mechanism and theory of sintering process, the process variables and furnaces used for sintering, liquid phase sintering, sintering kinetics, sintering technology, consolidation

Module 3: **(10 Hours)**

Pressureless powder shaping, Flow Sheets for the Production of the Following, Porous bearing, Sintered friction materials, Sintered carbides, Magnetic Materials, Cermets, Dispersion strengthened materials. Defects in P/M route and their control, treatment of powder metallurgy components

Module 4: **(06 Hours)**

Testing and quality control, metallic and ceramic P/M components, application of P/M products

Text Books:

1. Powder Metallurgy: science, technology and materials – Anish Upadhyaya, G.S. Upadhyaya, Universities Press (2011).
2. Powder Metallurgy: Science, Technology and Materials – P.C. Angelo, R. Subramanian, Prentice Hall India Learning Pvt. Ltd., (2008).

Reference Books:

1. ASM Handbook Volume 7: Powder Metallurgy, ASM International
2. Powder Metallurgy Science – R.M. German, Metal Powder Industry (1994)
3. Introduction to Powder Metallurgy, A.K. Sinha, Dhanpatrai Publisher.

CO-PO-PSO Mapping

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CO2	3	3	2	2	3	–	–	–	1	–	3	3	3	2
CO3	3	3	3	2	2	1	–	1	2	1	3	3	2	3
CO4	3	3	3	3	3	2	–	–	2	1	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester **PE-III**

Deformation Processing and Forming			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - III	Course Code:	MS3256

Prerequisite:

Deformation behaviour of Materials

Course Objectives:

1. To introduce the fundamental concepts and classifications of metal forming processes.
2. To explain the mechanics and parameters of key forming techniques like forging, rolling, extrusion, and drawing.
3. To assess the influence of process variables on product quality and identify common defects.
4. To develop skills in designing and optimizing metal forming operations for improved performance.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the fundamental principles of metal forming processes, including classification, mechanisms of metal working, and factors influencing flow stress, temperature, strain rate, and workability.

CO2: Analyze and apply the mechanics of various forming processes such as forging, rolling, extrusion, and drawing, focusing on their classifications, equipment, tooling, and process parameters.

CO3: Evaluate the impact of process variables on the quality and performance of formed products, identifying potential defects and implementing corrective measures.

CO4: Design and optimize forming processes by selecting appropriate materials, tools, and conditions to achieve desired product specifications and minimize defects.

Module 1: **(10 Hours)**

Introduction: - Classification of Forming Processes, Mechanism of metal working, Flow stress determination, Temperature in metal working, Strain-rate effect, Metallurgical structure, Friction and lubrication, Deformation-zone Geometry, hydrostatic pressure, Workability, residual

Classification of Forging Processes, forging in plane strain, Open-die forging, Closed-die forging, Forging loads in closed-die forging, forging defects, Residual stresses in forging. stresses.

Module 2: **(10 Hours)**

Classification of Rolling Processes, Types of rolling mills, Hot rolling, Cold rolling, Rolling of bars and shapes, Forces and Geometrical relationships in rolling, Analysis of rolling loads: Rolling variables, Defects in rolled products, Rolling mill control, Theories of Cold-rolling and hot-rolling.

Module 3: **(8 Hours)**

Classification of Extrusion Processes, Hot extrusion, Deformation, Lubrication and Defects in extrusion, Analysis of extrusion process, Cold extrusion and Hot forming, Hydrostatic extrusion, Extrusion of tubing, Seamless pipe.

Module 4: **(8 Hours)**

Drawing of Rods, Wires and Tubes: Rod and Wire drawing, Analysis of wire drawing, Tube drawing, Analysis of tube drawing, Residual stresses in rod, wire and tubes. Sheet-Metal Forming: Sheet metal forming methods, Shearing and blanking, Bending, Stretch forming, Deep drawing, Forming limit criteria, Defects in formed parts.

Text Books:

1. G. E. Dieter and David Bacon, Mechanical Metallurgy, McGraw-Hill, 1988, 3ed

Reference Books:

1. Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, John Wiley & Sons.
2. Meyers M. A. and Chawla K. K., Mechanical Behaviour of Materials, Cambridge University Press.
3. Courtney T.H., Mechanical Behaviour of Materials, McGraw Hill, New York, 2nd Edition, 2000. (ISBN0-07-028594-2).
4. DeGarmo E. P., Black J. T and Kohser R. A., Materials and Processes in Manufacturing (8^{th} Edition), Prentice Hall of India, New Delhi (ISBN 0-02-978760).
5. Ghosh A. and Mallik A.K., Manufacturing Science, Affiliated East-West Press Pvt.. Ltd.. New Delhi.

6. Benedict. G.F. and Dekker M., Non traditional Manufacturing Processes, Inc. New York (ISBN 0-8247-7352-7).

CO-PO-PSO Mapping

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CO2	3	3	3	2	2	–	–	–	1	–	3	3	2	2
CO3	3	3	3	2	2	2	1	–	1	–	3	3	2	3
CO4	3	3	3	2	3	2	–	1	2	1	3	3	2	3

Correlation Level 1: Slight 2: Moderate 3: High

6th Semester LC

Composite Materials Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Laboratory Course	Course Code:	MS3542

Course Objectives:

1. To provide hands-on experience in fabricating MMCs and CMCs using various processing techniques.
2. To develop skills in microstructural and mechanical characterization of composite materials.
3. To train students in the fabrication and evaluation of PMCs, including flexural testing and composition analysis.
4. To analyze the influence of processing parameters and apply testing methods for assessing composite performance.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Fabricate metal matrix composites (MMCs) and ceramic matrix composites (CMCs) using various processing techniques, including stir casting, powder metallurgy, sol-gel, and in-situ methods.

CO2: Characterize the microstructure and mechanical properties (such as hardness, tensile strength, and wear resistance) of fabricated composites, and compare them with monolithic materials.

CO3: Assess the performance of polymer matrix composites (PMCs) by fabricating glass fiber reinforced epoxy laminates and evaluating their flexural properties and constituent volume fractions.

CO4: Analyze the effects of processing parameters on the properties of composites, and apply appropriate testing methods to evaluate their suitability for various engineering applications.

List of experiments:

(Minimum 08 experiments)

1. Fabrication of Al-Ceramic particulate composite by stir casting method.
2. Fabrication of Ceramic matrix particulate composite by powder metallurgy route.
3. Fabrication of pure Cu and Cu-Al_2O_3 metal matrix composites and determination of their green and sintered densities.

4. Hardness measurement and microstructure analysis of pure Cu and Cu-Al_2O_3 composites.
5. Comparison of mechanical properties (Strength, Hardness, Wear) of MMC with monolith metals.
6. Fabrication of CMCs by Sol-Gel technique.
7. Fabrication of composites by insitu method.
8. Fabrication of Polymers and Polymer Matrix Composites.
9. Fabrication of glass fiber reinforced epoxy laminates using hand lay-up technique
10. Evaluation of flexural properties of the glass fiber reinforced epoxy composites.
11. Determination of density and volume fraction of the constituents in a glass fiber reinforced epoxy composite.

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CO2	3	3	2	3	3	-	-	-	1	-	2	3	3	2
CO3	3	2	3	2	3	-	-	-	1	-	1	2	3	2
CO4	3	3	3	3	3	1	1	1	2	1	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester LC

Corrosion Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Laboratory Course	Course Code:	MS3544

Course Objectives:

1. To train students in measuring electrochemical properties and analyzing polarization behaviour of metals.
2. To evaluate corrosion rates using techniques like Tafel extrapolation, weight loss, and impedance spectroscopy.
3. To study localized corrosion mechanisms such as galvanic corrosion and stress-corrosion cracking.
4. To analyze high-temperature oxidation behaviour of alloys through experimental testing and data interpretation.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Determine the electrochemical properties of metals by measuring their Electromotive Force (EMF) and analyzing polarization behavior using electrochemical workstations.

CO2: Evaluate corrosion rates through various methods, including Tafel extrapolation, weight loss measurements, and impedance spectroscopy, to assess material degradation.

CO3: Investigate localized corrosion phenomena such as galvanic corrosion between dissimilar metals and stress-corrosion cracking in steels under controlled environmental conditions.

CO4: Analyze oxidation behaviors **of** alloys by conducting high-temperature oxidation tests and interpreting the resulting data to understand material performance in aggressive environments.

List of Experiments:

1. Determination of EMFs of common metals.
2. Carryout Polarization Studies by using electrochemical workstation.
3. Evaluation of corrosion rate through Tafel plots.
4. Galvanic corrosion of copper-steel couple.
5. Stress-Corrosion Cracking of Steels.
6. Carry out Impedance studies by electrochemical workstation.

7. Determination of corrosion rate by weight loss measurements.
8. Find out rate of oxidation of alloys.

CO-PO-PSO Mapping

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CO2	3	3	2	3	3				1		2	3	3	2
CO3	3	3	2	3	2	2	1		1		2	3	3	3
CO4	3	3	2	3	3	2	1		1		2	3	3	3

Correlation Level 1: Slight 2: Moderate 3: High

7th Semester

7th Semester **PE-IV**

Fuels and Refractories			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - IV	Course Code:	MS4241

Prerequisite:

Iron and Steel making

Course Objectives:

1. To classify and characterize different types of fuels, with emphasis on coal properties and evaluation.
2. To study coal processing methods and their significance in metallurgical applications.
3. To understand the classification, properties, and production of refractory materials.
4. To apply phase diagram interpretation in the selection of refractories for industrial furnaces.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Classify and characterize various fuels (solid, liquid, and gaseous), focusing on coal, including its rank, caking properties, and calorific value.

CO2: Analyze and evaluate coal processing techniques such as washing, blending, and carbonization, and understand their impact on metallurgical applications.

CO3: Explain the properties and classifications of refractories, including their raw materials, manufacturing processes, and applications in high-temperature environments.

CO4: Interpret binary phase diagrams relevant to refractory materials and apply this knowledge to select appropriate refractories for various industrial furnaces.

Module 1: **(8 Hours)**

Fuels:

Classification of fuels: Solid, Liquid and Gaseous fuels, Primary and Secondary fuels.

Coal: Rank of coal, Caking, Coking and Non-coking coals.

Characterisation of Coal: Proximate Analysis, Ultimate Analysis, Calorific value, Caking and Swelling Index.

Module 2: **(10 Hours)**

Coal washing: Principle of coal washing, Washability curve, Washing efficiency (Yancey and Geer formula and Fraser and Yancey formula) and recovery of clean coal.

Coal blending and its importance in metallurgical industries.

Carbonisation of coal: Metallurgical coke preparation, Testing and properties of coke. Formed coke, Dry quenching of coke.

Use of gaseous fuels: Coke oven gas, Blast furnace gas, Producer gas.

Some coal combustion problems.

Module 3: **(9 Hours)**

Refractories:

Classification of refractories, raw materials, manufacture, testing and properties of heavy and special refractories, silica, siliceous alumino-silicate, high alumina, magnesite, chrome, chrome-magnesite, dolomite, forsterite, chemically bonded basic, carbon and insulating refractories and special purpose oxides, carbide nitride refractories.

Module 4: **(9 Hours)**

Binary phase diagrams of Al_2O_3-SiO_2, CaO-MgO, Cr_2O_3-MgO and MgO-SiO_2 systems.

Refractory mortars and cements, Refractory castables, selection of refractories for coke oven, iron blast furnace, copper convertor, soaking reheating furnaces and heat treatment furnaces, electric arc furnace.

Text Books:

1. Marion L. Smith and Karl W. Stinson, Fuels and Combustion McGraw-Hill Book Company, Inc. New York.
2. R.C. Gupta, Fuels, Furnaces and Refractories, PHI.
3. O.P. Gupta, Elements of Fuels, Furnaces & Refractories, Khanna Publishers.
4. F.H. Norton, Refractories, McGraw-Hill Inc.

Reference Books:

1. J.D. Gilchrist, Fuels, Furnaces and Refractories, Pergamon Press.
2. S.B. Pandya, Conventional Energy Technology – Fuels and Chemical Energy, Tata McGraw-Hill Publishing Co. Ltd., New Delhi.
3. Samir Sarkar, Fuels and Combustion, Orient Longman Ltd., Mumbai.

4. S.P. Sharma and C. Mohan, Fuels and Combustion, Tata McGraw-Hill Publishing Co. Ltd., New Delhi.
5. J. H. Chesters, Refractories Production and Properties, the Iron and Steel Institute.

CO-PO-PSO Mapping

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CO3	3	2	2	1	2	2	–	–	–	–	2	3	2	2
CO4	3	3	3	2	2	2	–	–	1	–	2	3	2	2

Correlation Level 1: Slight 2: Moderate 3: High

7th Semester **PE-IV**

Creep, Fatigue and Fracture			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - IV	Course Code:	MS4243

Prerequisite:

Deformation behaviour of Materials

Course Objectives:

1. To study the mechanisms of creep deformation and the development of creep-resistant materials.
1. To study fatigue failure and the factors influencing fatigue life of materials.
2. To analyze fatigue crack propagation and related microscopic mechanisms.
3. To apply fracture mechanics concepts for predicting material failure under stress.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze creep behavior in materials**,** including temperature-stress-strain rate relations, deformation mechanisms, and the development of creep-resistant alloys.

CO2: Examine fatigue failure mechanisms**,** focusing on cyclic stress and strain, fatigue life estimation, and the effects of various variables on fatigue life.

CO3: Investigate fatigue crack propagation**,** including microscopic mechanisms, crack growth behavior, and the concept of crack closure.

CO4: Apply fracture mechanics principles**,** such as stress intensity factor, fracture toughness, and J-integral, to assess material behavior under stress and predict failure.

Module 1: (11 Hours)

Creep: An overview on creep of solids, Temperature-stress-strain rate relations, Stress-rupture test, Structural changes during creep, Elevated temperature deformation mechanisms, deformation mechanism maps, Superplasticity, Fracture at elevated temperature, Use of creep and stress rupture data for life prediction, Development of creep resistant alloys.

Module 2: (7 Hours)

Fatigue: Cyclic stress and cyclic strain controlled fatigue, Fatigue life estimation of notched components, Structural features of fatigue, Fatigue initiation mechanism, Surface effects and fatigue, Effects of different variables on fatigue life.

Module 3: **(7 Hours)**

Fatigue crack propagation, Microscopic fatigue fracture mechanism, Crack growth behaviour at low, intermediate and high ΔK, Crack closure concept, Corrosion fatigue, Creep-fatigue interaction.

Module 4: **(11 Hours)**

Fracture: Strain energy release rate, Concept of stress intensity factor and fracture toughness, K_{Ic} Plain strain fracture toughness, Plastic zone, Principles of linear elastic and elastic-plastic fracture toughness testing, Test procedure related to K_{Ic}, CTOD and J Integral, R Curve, Effect of microstructure, environment and strain rate on fracture toughness of materials.

Text Books:

1. Fatigue of Materials, S. Suresh, Cambridge India, 2015
2. Fracture Mechanics, Fundamentals and Applications, T.L. Anderson, CRC Press 2017
3. Mechanical Metallurgy by George E. Dieter, McGraw Hill

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	2	-	-	-	1	-	2	3	2	2
CO2	3	3	2	2	2	-	-	-	1	-	2	3	3	2
CO3	2	3	2	3	2	-	-	-	1	-	2	3	3	3
CO4	3	3	3	3	3	-	-	-	1	-	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

7th Semester **PE-IV**

Non-Destructive Testing Methods			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective – IV	Course Code:	MS4245

Course Objectives:

1. To introduce the principles, classifications, and applications of various Non-Destructive Testing (NDT) methods.
2. To develop skills in performing and interpreting Liquid Penetrant, Magnetic Particle, and Eddy Current Testing.
3. To train students in the use of Radiographic and Ultrasonic Testing for evaluating material integrity.
4. To explore the application of Acoustic Emission Testing for structural health monitoring and early defect detection.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Classify various Non-Destructive Testing (NDT) methods, including their principles, advantages, limitations, and applications.

CO2: Demonstrate proficiency in conducting and interpreting results from Liquid Penetrant Testing (PT), Magnetic Particle Testing (MT), and Eddy Current Testing (ET).

CO3: Apply Radiographic Testing (RT) and Ultrasonic Testing (UT) techniques to assess material integrity, ensuring safety and compliance with industry standards.

CO4: Utilize Acoustic Emission Testing (AET) for monitoring structural health and detecting early signs of material degradation.

Module 1: **(10 Hours)**

Introduction: Introduction to NDT, Classification of NDT processes; advantages and limitations of NDT

Eddy Current Testing and Liquid penetrant testing: Principle, Advantages, Limitations and applications of eddy current testing; Liquid penetrant testing - Principle, Advantages, Limitations and applications.

Module 2: **(8 Hours)**

Magnetic Particle Testing: Principle, Procedure, Magnetic media, Methods to generate magnetic fields, Method of De-Magnetization, Interpretation of indications, Advantages, limitations and applications.

Module 3: **(8 Hours)**

Radiographic Testing: Principle, Gamma radiography, X-ray radiography and Neutron radiography, Imaging modalities, Radiograph Interpretation, Precautions against radiation hazards.

Module 4: **(10 Hours)**

Ultrasonic Testing and Acoustic Emission Testing: Principles of ultrasonic testing, Ultrasonic propagation, Test techniques – normal and angle beam, Probes, Transducers, Applications, Advantages and limitations of ultrasonic testing.

Acoustic emission testing – principle, sources of acoustic emission, acoustic emission signal parameters, industrial applications

Text Books:

1. Practical Non-Destructive Testing, Baldev Raj, T. Jayakumar, M. Thavasimuthu, Narosa Publishing House, 2014.
2. Non-Destructive Testing Techniques, Ravi Prakash, New Age International Publishers, 1st revised edition, 2010.

Reference Books:

1. Non-Destructive Testing - Theory, Practice and Industrial Applications, Wong B Stephen, LAP Lambert Academic Publishing, USA, 1st edition, 2014.
2. Non Destructive Test and Evaluation of Materials, J. Prasad and C. G. K. Nair, Tata McGraw-Hill Education, 2011, 2nd edition.
3. ASM Metals Handbook, Non-Destructive Evaluation and Quality Control, American Society of Metals, Metals Park, Ohio, USA, Volume-17.
4. Charles, J. Hellier, Handbook of Non-destructive evaluation, Charles, J. Hellier, McGraw Hill, New York, 2001.
5. Paul E Mix, Introduction to Non-destructive testing: a training guide, Wiley, 2nd Edition New Jersey, 2005

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	2	-	-	-	1	-	2	3	2	2
CO2	2	3	2	3	3	-	-	1	2	-	2	2	3	2
CO3	3	3	3	3	3	2	1	1	2	1	3	2	3	3
CO4	2	3	2	3	3	2	1	-	2	1	3	2	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

7th Semester **PE-IV**

Joining of Metals			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - IV	Course Code:	MS4247

Course Objectives:

1. To study the principle of metal joining.
2. To get acquainted with different welding techniques.
3. To compare and contrast welding, brazing, and soldering processes.
4. To study weldability, welding stresses, and welding defects.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze and articulate the principles, theories, and classifications of various welding and joining processes, including Manual Metal Arc (MMA), Submerged Arc Welding (SAW), Gas Metal Arc Welding (GMAW), Tungsten Inert Gas (TIG) welding, Resistance Welding, Soldering, and Brazing.

CO2: Demonstrate proficiency in selecting appropriate welding techniques and parameters, such as electrode types, shielding gases, and power sources, to optimize welding performance for different materials and applications.

CO3: Analyze and interpret the welding metallurgy of various materials, including carbon and alloy steels, cast irons, stainless steels, and non-ferrous alloys, focusing on weldability, heat-affected zones (HAZ), and potential welding defects.

CO4: Identify, evaluate, and mitigate common welding defects through appropriate detection techniques, ensuring the production of high-quality welded joints.

Module 1: **(8 Hours)**

Introduction: Principle, Theory and Classification of welding and other joining processes. Manual metal arc (MMA): Equipment requirement, electrodes for welding of structural steels, coating constituents and their functions, types of coatings, current and voltage selection for electrodes,

Arc welding power sources Conventional welding transformers, rectifiers and current and voltage. The influence of these power sources on welding. Metal transfer.

Module 2: **(10 Hours)**

Submerged arc welding (SAW): Process details, consumables such as fluxes and wires for welding mild steel, Variations in submerged arc welding process.

Gas metal arc welding (GMAW) or MIG/ MAG welding: Process details, shielding gases, electrode wires, their sizes, and welding current ranges.

TIG welding: Process details, power sources requirements, electrode sizes and materials, current carrying capacities of different electrodes, shielding gases, application of process.

Module 3: (8 Hours)

Resistance welding: General principle of heat generation in resistance welding, application of resistance welding processes.

Process details and working principle of spot, seam, and. projection welding, electrode materials, shapes of electrodes, electrode cooling, selection of welding currents, voltages.

Module 4: (10 Hours)

Welding metallurgy of carbon and alloy steels, Cast irons, Stainless steels, Al- and Cu-based alloys.

Weldability and Heat affected zones (HAZ).

Welding defects and detection techniques.

Soldering and brazing: Difference between both the processes, consumables used, methods of brazing, fluxes used, their purposes and flux residue treatment.

Text Books:

1. J F Lancaster, Metallurgy of Welding, Allen
2. R L Little, Welding and Welding Technology, TMH

Reference Books:

1. J. Norrish, Advanced Welding Processes, Woodhead
2. K Weman, Welding Processes Handbook, Wiidhead

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	2	-	-	-	1	-	2	3	2	2
CO2	3	3	3	2	3	1	1	-	2	-	3	3	3	3
CO3	3	3	3	3	2	1	1	-	2	1	3	3	3	3
CO4	2	3	2	3	3	2	1	-	2	-	3	2	3	3

Correlation Level 1: Slight 2: Moderate 3: High

7th Semester **PE-V**

Nanomaterials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - V	Course Code:	MS4249

Course Objectives:

1. To introduce the fundamentals of nanomaterials, their types, synthesis methods, and associated challenges.
2. To study the properties and applications of key nanomaterials, including carbon-based, semiconducting, and magnetic types.
3. To evaluate size-dependent properties of nanomaterials and related physical phenomena.
4. To develop proficiency in advanced techniques for characterizing nanomaterials and understanding their technological applications.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the fundamental concepts of nanomaterials, including their types, synthesis techniques (bottom-up and top-down approaches), and the challenges faced in nanotechnology.

CO2: Analyze the properties and diverse applications of specific nanomaterials such as carbon nanostructures (nanotubes, graphene), semiconducting nanomaterials (quantum dots, wells, wires), magnetic nanomaterials, and nanocomposites.

CO3: Evaluate the thermodynamic, mechanical, electrical, optical, and magnetic properties of nanomaterials, including phenomena like the inverse Hall-Petch relationship and quantum confinement effects.

CO4: Employ advanced characterization techniques (BET, XRD, SEM, TEM, AFM, EDS, etc.) to study nanomaterials and explore their applications in medicine, energy, environment, and information and communication technology.

Module 1: **(10 Hours)**

Introduction: Types of nanomaterials, emergence of nanotechnology, bottom-up and top-down approaches, challenges in nanotechnology. Nanoparticles: synthesis of metallic nanoparticles, semiconductor nanoparticles, oxide nanoparticles (sol-gel processing); vapour phase reactions, solid phase segregation. Nanowires: Synthesis of nanowires by evaporation – condensation growth, VLS or SLS growth, high energy ball milling, cryo rolling, and equal channel angular extrusion, template-based synthesis, electrospinning, types of lithography. Thin Films: fundamentals of film growth, PVD, CVD and ALD. Rapid Solidification Processes.

Module 2: **(9 Hours)**

Specific nano materials and their applications: Carbon nanostructures (Nanotubes, nanohorns, graphene, buckyballs etc.), Semiconducting nanomaterials – Quantum confinement, Quantum wells, quantum wires and quantum dots. Magnetic nanomaterials – super paramagnetism, Ferroelectric, nano ceramics, Super plasticity, Nanocomposites and their types.

Module 3: **(9 Hours)**

Thermodynamics of nanomaterials, Mechanical property aspects of nanomaterials, inverse Hall-Petch relationship, nano indentation, electrical properties of nanomaterials, optical properties of nanomaterials, magnetic properties of nanomaterials,

Module 4: **(9 Hours)**

Characterization techniques from the perspective of nanomaterials: BET, XRD, SEM, TEM, AFM, EDS, WDS, LEED, XPS etc.

Application of nanomaterials such as medicine, energy, environment, information and communication technology.

Text Books:

1. Rishal Singh, S.M. Gupta, Introduction to nanotechnology, Oxford university press, (2016).
2. Dieter Vollath. Nanomaterials: An Introduction to Synthesis, Properties and Applications, Second Edition. Published 2013 by Wiley-VCH Verlag GmbH & Co. KGaA.

Reference Books:

1. Charles Poole and Frank Owens, Introduction to Nanomaterials, Wiley 2007
2. Cao G., Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press
3. Gagotsi Y., Nano-materials Handbook, (Ed.), Taylor and Francis.
4. Edlstein and Cammarate, Nano Materials Synthesis, Properties and Applications.
5. Bandyopadyay A.K., Nano Materials, New age Publications.
6. Pradeep T., Nano - The Essentials, TMH.
7. Koch. C, Nanostructured Materials: Processing, Properties and applications, William Andrew Publishing.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	2	1	-	-	1	-	3	3	2	2
CO2	3	3	2	2	2	2	1	-	1	-	3	3	2	3
CO3	3	3	3	2	2	1	-	-	1	-	3	3	3	3
CO4	3	3	3	3	3	2	1	1	2	1	3	2	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

7th Semester **PE-V**

Biomaterials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - V	Course Code:	MS4251

Course Objectives:

1. To introduce the fundamental principles of biomaterials science, including biocompatibility and cell-material interactions.
2. To study bone tissue properties, biocompatibility evaluation methods, and corrosion behaviour of implants.
3. To explore the processing, characteristics, and applications of major metallic and ceramic biomaterials.
4. To study and apply advanced fabrication techniques for designing bio-implants and tissue engineering scaffolds.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the fundamental concepts of biomaterials science including biocompatibility, cell-material interactions, and biological cell and tissue properties.

CO2: Analyze bone tissue structure and properties, evaluate biocompatibility using in vitro biochemical assays and in vivo testing, and understand corrosion behavior of biomedical implants.

CO3: Evaluate the processing, properties, and applications of important biomaterials such as Ti-based alloys, stainless steels, Co-Cr-Mo alloys, bioactive ceramics, and biocompatible coatings.

CO4: Apply advanced fabrication techniques like electrospinning and 3D printing to develop porous scaffold materials, and understand the design concepts for new bio-implant materials.

Module 1: **(10 Hours)**

Introduction to basic concepts of Materials Science, Salient properties of important material classes, Property requirement of biomaterials, Concept of biocompatibility, Structure and properties of biological cells & tissues, Cell fate processes (cell migration, cell differentiation, cell apoptosis, cell division), Cell signaling processes, Cell-material interactions and foreign body response

Module 2: **(10 Hours)**

Bone tissue–structure, bone tissue-property, assessment of biocompatibility of biomaterials, in vitro biochemical assays (cellular adhesion, cellular viability using MTT, osteogenic differentiation- ALP assay; Bio-mineralization - Osteocalcin assay), In vivo testing and histocompatibility assessment, Genotoxicity assessment, corrosion of bio implants.

Module 3: **(08 Hours)**

Important bio-metallic alloys: Ti-based, stainless steels, Co-Cr-Mo alloys Bioinert, Bioactive and Bioresorbable ceramics**,** Processing and properties of different hydroxyapatite (HA)-based bio-composites, Synthesis of biocompatible coatings on structural implant materials, ,

Module 4: **(08 Hours)**

Fabrication of porous scaffold materials using electrospinning and 3D printing, Microstructure and properties of glass-ceramics; biodegradable polymers, Processing and Properties of some Polymer-based Bio-composites

Design concept of developing new materials for bio-implant applications

Text Books:

1. Introduction to Biomaterials: Basic Theory with Engineering Applications; C.L Agrawal, J.L. Ong, Mark R Appleford, Gopinath Mani, Cambridge University Press, 2013

Reference Books:

1. Biological Performance of Materials: Fundamentals of Biocompatibility (Third Edition, Revised and Expanded); Author: Jonathan Black; Publisher - Marcel Dekker, 1999
2. Biomaterials Science and Biocompatibility; Authors: Frederick H. Silver and David L. Christiansen; Publisher: Springer-Verlag New York, 1999
3. Biomaterials Science: An Introduction to Materials in Medicine; Editors: Buddy D. Ratner, Allan S. Hoffman, Fredrick J. Schoen and Jack E. Lemons; Publisher: Elsevier Inc., 2004
4. Molecular Biology of the Cell; Fourth edition; Authors: Bruce Alberts, Alexander Johnson, Julian Lewis, Keith Roberts and Peter Walter; Publisher: Taylor & Francis, New York, 2002
5. B. Basu, D. Katti and Ashok Kumar; Advanced Biomaterials: Fundamentals, Processing and Applications; John Wiley & Sons, Inc., USA, September, 2009.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	2	2	2	-	1	-	3	3	2	2
CO2	3	3	2	3	3	3	2	-	2	-	3	3	3	3
CO3	3	3	3	2	3	2	1	-	2	1	3	3	3	3
CO4	3	3	3	3	3	2	1	1	2	1	3	2	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

7th Semester **PE-V**

Energy Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - V	Course Code:	MS4253

Course Objectives:

1. To analyze global and national energy demands and trends.
2. To study various energy storage and conversion technologies.
3. To evaluate the environmental impacts of different energy systems.
4. To explore materials selection strategies for sustainable energy solutions.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Assess Global and Indian Energy Needs

CO2: Analyze Energy Storage and Conversion Technologies

CO3: Evaluate Environmental Impacts of Energy Systems

CO4: Integrate Materials Selection in Sustainable Energy Systems

Module 1: **(5 Hours)**

Energy requirements in a global scale and in the Indian context.

Evaluation of energy sources from the perspective of clean energy. Carbon equivalent

Module 2: **(9 Hours)**

Introduction to different types of energy storage and conversion devices and technologies. Synthesis and characterization of materials used for these technologies, Properties desired in the materials, Techniques to evaluate the properties and performance, failure modes and analysis,

Module 3: **(10 Hours)**

Environmental impact of the following technologies: Fuel cells, Batteries, Supercapacitors

Module 4: **(10 Hours)**

Environmental impact of Solar energy conversion devices, Wind, Mechanical Energy storage

Text Books:

1. Renewable Energy: Power for a Sustainable Future, Godfrey Boyle, Oxford University Press, 2004

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	2	2	1	-	-	3	1	-	1	-	3	1	1	2
CO2	3	3	2	2	2	3	1	-	1	-	3	2	2	3
CO3	2	3	2	2	2	3	2	-	2	1	3	2	2	3
CO4	3	3	3	2	3	3	2	1	2	1	3	3	3	3

Correlation Level 1: Slight 2: Moderate 3: High

7th Semester **PE-V**

History and Evolution of Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Professional Elective - V	Course Code:	MS4255

Course Objectives:

1. To dive into the history of materials and chronologically understand the evolution of major classes of manmade materials from the stone-age to the present day.
2. To learn the traditional materials manufacturing techniques prevalent in ancient and present India.
3. To study how metals and minerals can be transformed based on ancient Indian alchemy.
4. Revive the glorious Indian metallurgical heritage and traditions and their supremacy in the ancient and medieval world.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the Foundations of Materials Science

CO2: Trace the Evolution of Materials Through History

CO3: Examine Ancient Indian Metallurgical Practices

CO4: Analyze the Significance of Iconic Indian Metallurgical Achievements

Module 1: **(8 Hours)**

Introduction

Introduction to materials science and engineering, brief introduction to atomic structure, atomic bonding, crystallography, different properties of materials and their relation with structure of materials. Short introduction to different mechanical properties. Introduction to different classes of materials.

The timeline of evolution of materials since the stone age until today. The evolution of material-property space with time.

Module 2: **(8 Hours)**

Motivation and Introduction to Ancient India

The urgency to learn the history of materials and its pivotal role in the progressive evolution of materials in ancient India that is, Bharat. Introduction to the ages of civilization: the stone, bronze, and iron ages. The rivers and civilizations in ancient India. The metallurgy of gold

based on ancient Vedic and other texts of Bharat. Reference to the structural and functional properties of metals and materials in the ancient Vedic and other texts of Bharat.

Module 3: **(10 Hours)**

Metallurgy in ancient India

Brief accounts of the evidence and metallurgy of copper (loha, tamra), bronze (kamsya), gold (hiranya), silver (rajat-hiranyam), lead (sisam), zinc (rasaka), and brass (rtika, pitala), The materials and technology unraveled from the archaeological excavations at Harappa, Mohenjo-Daro, Lothal, etc. The primacy of Bharat in brass and zinc metallurgy.

Metal Casting Traditions in ancient India

Madhucchistavidhana: the lost-wax process of casting.

The hereditary metal casting traditions and handicrafts prevalent in Bharat.

Case study of the bronze casting in Swami Malai and the Aranmula metal-mirror (Kannadi) craft traditions.

Module 4: **(10 Hours)**

The Emergence of Iron in ancient India

The legendary Wootz steel (ukku) and its connection with the Damascus steel.

The making of Delhi Iron Pillar and its exemplary nature.

Declining interest in Wootz steel, and the advent of modern steel making in India.

Rasa-Ratna-Samuccaya

The essence of the Rasa-Ratna-Samuccaya, a 13th century alchemical treatise presenting the state of Indian expertise in the field of alchemy related to the extraction, purification, conversion of metals/minerals into therapeutically useful forms for treatment of various diseases.

Text Books:

1. A.K. Biswas, Minerals and Metals in Ancient India (Vol. 1 and Vol. 2), D.K. Print World Pvt. Ltd., 1996.
2. R. Balasubramaniam, Marvels of Indian Iron through the Ages, Rupa Publication Pvt. Ltd. , 2008.

Reference Books:

1. R. Srivastava, Mining and Metallurgy in Ancient India, M.M. Publishers Pvt. Ltd., 2006.
2. T.R. Anantharaman, The Rustless Wonder: A Study of the Iron Pillar at Delhi, Vigyan Prasar, 1996.

Journal and Conferences:

1. Arun Kumar Biswas, The primacy of India in ancient brass and zinc metallurgy, Indian Journal of History of Science, Volume 28, pages 309-330, 1993.
2. S. Srinivasan, S. Ranganathan, Tamil Chola Bronzes and Swami Malai Legacy: Metal Sources and Archaeotechnology, The Journal of The Minerals, Metals & Materials Society (TMS), Volume 68, pages 2207-2221, 2016.

CO-PO-PSO Mapping

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CO1	3	2	1	-	-	2	1	-	1	-	3	3	1	1
CO2	3	2	2	-	-	2	1	-	1	-	3	3	1	2
CO3	3	2	1	-	-	2	2	-	2	-	3	3	1	2
CO4	3	2	2	1	1	3	2	-	2	1	3	2	2	2

Correlation Level **1: Slight** **2: Moderate** **3: High**

Open Electives offered by Metallurgical and Materials Engineering

7th Semester **Open Elective – I**

History and Evolution of Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Open Elective - I	Course Code:	MS4341

Course Objectives:

1. To dive into the history of materials and chronologically understand the evolution of major classes of manmade materials from the stone-age to the present day.
2. To learn the traditional materials manufacturing techniques prevalent in ancient and present India.
3. To understand how metals and minerals can be transformed based on ancient Indian alchemy.
4. Revive the glorious Indian metallurgical heritage and traditions and their supremacy in the ancient and medieval world.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the Foundations of Materials Science

CO2: Trace the Evolution of Materials Through History

CO3: Examine Ancient Indian Metallurgical Practices

CO4: Analyze the Significance of Iconic Indian Metallurgical Achievements

Module 1: **(8 Hours)**

Introduction

Introduction to materials science and engineering, brief introduction to atomic structure, atomic bonding, crystallography, different properties of materials and their relation with structure of materials. Short introduction to different mechanical properties. Introduction to different classes of materials.

The timeline of evolution of materials since the stone age until today. The evolution of material-property space with time.

Module 2: **(8 Hours)**

Motivation and Introduction to Ancient India

The urgency to learn the history of materials and its pivotal role in the progressive evolution of materials in ancient India that is, Bharat. Introduction to the ages of civilization: the stone, bronze, and iron ages. The rivers and civilizations in ancient India. The metallurgy of gold based on ancient Vedic and other texts of Bharat. Reference to the structural and functional properties of metals and materials in the ancient Vedic and other texts of Bharat.

Module 3: **(10 Hours)**

Metallurgy in ancient India

Brief accounts of the evidence and metallurgy of copper (loha, tamra), bronze (kamsya), gold (hiranya), silver (rajat-hiranyam), lead (sisam), zinc (rasaka), and brass (rtika, pitala), The materials and technology unraveled from the archaeological excavations at Harappa, Mohenjo-Daro, Lothal, etc. The primacy of Bharat in brass and zinc metallurgy.

Metal Casting Traditions in ancient India

Madhucchistavidhana: the lost-wax process of casting.

The hereditary metal casting traditions and handicrafts prevalent in Bharat.

Case study of the bronze casting in Swami Malai and the Aranmula metal-mirror (Kannadi) craft traditions.

Module 4: **(10 Hours)**

The Emergence of Iron in ancient India

The legendary Wootz steel (ukku) and its connection with the Damascus steel.

The making of Delhi Iron Pillar and its exemplary nature.

Declining interest in Wootz steel, and the advent of modern steel making in India.

Rasa-Ratna-Samuccaya

The essence of the Rasa-Ratna-Samuccaya, a 13th century alchemical treatise presenting the state of Indian expertise in the field of alchemy related to the extraction, purification, conversion of metals/minerals into therapeutically useful forms for treatment of various diseases.

Text Books:

1. A.K. Biswas, Minerals and Metals in Ancient India (Vol. 1 and Vol. 2), D.K. Print World Pvt. Ltd. , 1996.
2. R. Balasubramaniam, Marvels of Indian Iron through the Ages, Rupa Publication Pvt. Ltd., 2008.

Reference Books:

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CO1	3	2	-	-	-	-	-	-	-	-	3	3	-	-
CO2	2	2	-	-	-	1	-	-	1	-	3	2	1	1
CO3	2	2	-	1	-	2	1	-	2	-	3	3	2	2
CO4	2	3	-	2	-	3	2	-	2	-	3	3	2	2

Correlation Level 1: Slight 2: Moderate 3: High

7th Semester **Open Elective – I**

Ironmaking and Steelmaking			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Open Elective - I	Course Code:	MS4343

Course Objectives:

1. To study the physical and chemical processes in blast furnace operations, including burden preparation and slag control.
2. To analyze primary and secondary steelmaking methods and their role in refining steel quality.
3. To compare conventional and alternative ironmaking techniques.
4. To explore ingot and continuous casting processes with focus on solidification, heat transfer, and defect control.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the physical, thermal, and chemical processes occurring in a blast furnace, including burden preparation and slag control.

CO2: Evaluate modern steelmaking routes such as oxygen and electric arc furnaces, and understand secondary steelmaking processes like ladle desulfurization and inclusion control.

CO3: Compare the alternative methods of iron making.

CO4: Apply knowledge of casting techniques, including ingot and continuous casting, to understand steel solidification, heat transfer, and defect formation.

Module 1: **(11 hours)**

Introduction: Blast Furnace Route for Iron Making, The Blast Furnace and its accessories, The burden and its preparation, Physical – Thermal and Chemical process in a Blast Furnace, Blast Furnace slag and its control, Control of hot metal composition, Blast Furnace plant and Accessories, Modern trends in Blast Furnace practice, Control of irregularities in the blast furnace, Performance of Blast Furnace over the years.

Module 2: **(8 hours)**

Alternative Methods: Need for alternative Methods, Sponge Iron production by using solid and gaseous reductants, Smelting Reduction Processes;

Module 3: **(10 hours)**

Modern Steel Making: Different routes of steelmaking. Oxygen Steelmaking: Top and Bottom blown converter processes, Hybrid processes. Electric Steel making: Electric Arc furnaces, Induction furnaces. Secondary Steelmaking;

Module 4: **(7 hours)**

Casting of liquid steel: Ingot Casting of Steel, Continuous Casting of Steel;

Iron and Steel Scenario in India in the last decade.

Text Books:

1. A. Ghosh and A. Chatterjee: Ironmaking and Steelmaking Theory and Practice, Prentice-Hall of India Private Limited, 2008.
2. Dipak Mazumdar, "A First Course in Iron and Steel Making", Universities press – IIM, Series in Metallurgy and Materials Science, India, 2015.
3. Tupkary, R. H. &Tupkary V.R., "An Introduction to Modern Iron Making", Khanna Publishers, 4th edition, 2016, "An Introduction to Modern Steel Making", Khanna Publishers, New Delhi, 2000.

Reference Books:

1. A.K. Biswas: Principles of Blast Furnace Iron making, SBA Publication,1999.
2. D.H. Wakelin (ed.): The Making, Shaping and Treating of Steel (Iron making Volume), The AISE Steel Foundation, 2004.
3. R.J. Fruehan (ed.): The Making, Shaping and Treating of Steel (Steel making Volume), The AISE Steel Foundation, 2004.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	1	3	1	-	1	-	2	3	2	3
CO2	3	3	3	3	2	3	2	-	2	-	3	3	3	3
CO3	3	2	2	2	1	3	2	-	1	-	2	3	2	2
CO4	3	2	2	3	3	2	2	-	2	-	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

Mechatronics and IoT			
Hours/Week L-T-P :	3-0-0	Credits:	2
Course Type:	PC (ACC)	Course Code:	MS4141

Prerequisite: Basic Electronics Engg, Basic Electrical Engg.

Course Objectives:

1. To make students get acquainted with the sensors and the actuators, which are commonly used in mechatronics systems.
2. To provide insight into the signal conditioning circuits, and also to develop competency in PLC programming and control
3. To make students familiarize with the fundamentals of IoT and Embedded systems.
4. To inculcate skills in the design and development of mechatronics and IoT based systems.

Course Outcomes:

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

CO1: Identify and classify various sensors and actuators used in mechatronic systems.

CO2: Design basic signal conditioning circuits and develop logic control programs using PLC.

CO3: Explain the architecture and components of IoT and embedded systems for automation.

CO4: Develop and integrate embedded systems for Mechatronics and IoT-based applications.

Module I: **7 Hours**

Introduction to Mechatronics – Modular Approach, Sensors & Transducers: Static and Dynamic Characteristics, Transducers: Resistive, Capacitive, Inductive, Resonant, Optical Sensors: Photodetectors, Vision Systems, Laser, Piezoelectric & Ultrasonic Sensors, Actuators: DC/AC Servo motors, Stepper motors (PM, VR, Hybrid), Brushless DC motors, Basic control principles for actuators

Module II: **8 Hours**

Operational amplifiers: Inverting, Non-inverting, Instrumentation amplifier, Signal Conditioning: Protection, filtering, Wheatstone bridge, PID control, Power electronics: TRIAC, thyristors, MOSFETs, relays, Programmable Logic Controllers (PLCs): Architecture and I/O processing, Ladder logic and functional block programming, Timers, counters, and basic applications

Module III: **8 Hours**

Introduction to IoT and enabling technologies, Embedded system types: Single-chip microcontrollers, Single-board microcontrollers, Single-board computers, Peripherals and I/O devices, IoT framework and implementation procedure

Module IV: **7 Hours**

Foundation topics: Programming Languages: C++ and Python - The Linux Operating System. Arduino: The Arduino Boards - Arduino Peripherals- Arduino IDE – ESP8266 Wi-Fi module. Raspberry Pi: The Raspberry Pi Boards - The Raspberry Pi Peripherals - The Raspberry Pi Operating System. (typical peripherals) Interfacing and Controlling I/O devices by Arduino and Raspberry Pi: LEDs - Push buttons - Light intensity sensor - Ultrasonic distance sensor – Temperature sensor- Humidity sensor - Sensor and Actuator interactions. Case Studies

Text Books:

1. Bradley D.A., Burd N.C., Dawson D., Loader A.J., "Mechatronics: Electronics in Products and
2. Processes", Routledge, 2017.
3. Sami S.H and Kisheen Rao G "The Internet of Mechanical Things: The IoT Framework for
4. Mechanical Engineers", CRC Press, 2022.
5. David H., Gonzalo S., Patrick G., Rob B. and Jerome H., "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things", Pearson Education, 2018.
6. A. Bahga & V. Madisetti, Internet of Things – A Hands-on Approach, Universities Press, 2014.

Reference Books:

1. Nitin G and Sharad S, "Internet of Things: Robotic and Drone Technology", CRC Press, 2022
2. Newton C. Braga, "Mechatronics for The Evil Genius", McGraw-Hill, 2005.
3. Bell C., "Beginning Sensor Networks with Arduino and Raspberry Pi", Apress, 2013
4. Raj Kamal, Internet of Things: Architecture and Design Principles, McGraw-Hill Education, 2017.

CO-PO-PSO Mapping

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO 2	PSO3
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CO2	2	3	3	2	3	2	1	1	2	2	1	1	2	3
CO3	2	2	2	2	3	2	2	1	2	2	1	1	2	3

CO4	3	3	3	2	3	2	2	1	2	2	2	1	2	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

8th Semester

Nanomaterials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Open Elective - II	Course Code:	MS4342

Course Objectives:

1. To introduce the fundamentals, classification, and synthesis methods of nanomaterials.
2. To study the properties and applications of various types of nanomaterials.
3. To evaluate key physical phenomena influencing nanomaterial behaviour.
4. To develop skills in advanced characterization techniques and explore nanomaterial applications across sectors.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the fundamental concepts of nanomaterials, including their types, synthesis techniques (bottom-up and top-down approaches), and the challenges faced in nanotechnology.

CO2: Analyze the properties and diverse applications of specific nanomaterials such as carbon nanostructures (nanotubes, graphene), semiconducting nanomaterials (quantum dots, wells, wires), magnetic nanomaterials, and nanocomposites.

CO3: Evaluate the thermodynamic, mechanical, electrical, optical, and magnetic properties of nanomaterials, including phenomena like the inverse Hall-Petch relationship and quantum confinement effects.

CO4: Employ advanced characterization techniques (BET, XRD, SEM, TEM, AFM, EDS, etc.) to study nanomaterials and explore their applications in medicine, energy, environment, and information and communication technology.

Module 1: **(10 Hours)**

Introduction: Types of nanomaterials, emergence of nanotechnology, bottom-up and top-down approaches, challenges in nanotechnology. Nanoparticles: synthesis of metallic nanoparticles, semiconductor nanoparticles, oxide nanoparticles (sol-gel processing); vapour phase reactions, solid phase segregation. Nanowires: Synthesis of nanowires by evaporation – condensation growth, VLS or SLS growth, high energy ball milling, cryo rolling, and equal channel angular extrusion, template-based synthesis, electrospinning, types of lithography. Thin Films: fundamentals of film growth, PVD, CVD and ALD. Rapid Solidification Processes.

Module 2: **(9 Hours)**

Specific nano materials and their applications: Carbon nanostructures (Nanotubes, nanohorns, graphene, buckyballs etc.), Semiconducting nanomaterials – Quantum confinement, Quantum wells, quantum wires and quantum dots. Magnetic nanomaterials – super paramagnetism, Ferroelectric, nano ceramics, Super plasticity, Nanocomposites and their types.

Module 3: **(9 Hours)**

Thermodynamics of nanomaterials, Mechanical property aspects of nanomaterials, inverse Hall-Petch relationship, nano indentation, electrical properties of nanomaterials, optical properties of nanomaterials, magnetic properties of nanomaterials,

Module 4: **(9 Hours)**

Characterization techniques from the perspective of nanomaterials: BET, XRD, SEM, TEM, AFM, EDS, WDS, LEED, XPS etc.

Application of nanomaterials such as medicine, energy, environment, information and communication technology.

Text Books:

1. Rishal Singh, S.M. Gupta, Introduction to nanotechnology, Oxford university press, (2016).
2. Dieter Vollath. Nanomaterials: An Introduction to Synthesis, Properties and Applications, Second Edition. Published 2013 by Wiley-VCH Verlag GmbH & Co. KGaA.

Reference Books:

1. Charles Poole and Frank Owens, Introduction to Nanomaterials, Wiley 2007
2. Cao G., Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press
3. Gagotsi Y., Nano-materials Handbook, (Ed.), Taylor and Francis.
4. Edlstein and Cammarate, Nano Materials Synthesis, Properties and Applications.
5. Bandyopadyay A.K., Nano Materials, New age Publications.
6. Pradeep T., Nano - The Essentials, TMH.
7. Koch. C, Nanostructured Materials: Processing, Properties and applications, William Andrew Publishing.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	2	2	1	-	1	-	3	3	2	2
CO2	3	3	2	2	2	3	2	-	2	-	3	3	3	3
CO3	3	3	2	3	2	2	2	-	2	-	3	3	3	3
CO4	3	3	2	3	3	3	2	-	2	-	3	3	3	3

Correlation Level	1: Slight	2: Moderate	3: High

8th Semester **Open Elective – II**

Energy Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Open Elective - II	Course Code:	MS4344

Course Objectives:

1. To assess current and future energy demands at global and national levels.
2. To learn and analyze various energy storage and conversion technologies.
3. To evaluate the environmental implications of different energy systems.
4. To integrate materials selection principles in designing sustainable energy solutions.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Assess Global and Indian Energy Needs

CO2: Analyze Energy Storage and Conversion Technologies

CO3: Evaluate Environmental Impacts of Energy Systems

CO4: Integrate Materials Selection in Sustainable Energy Systems

Module 1: **(5 Hours)**

Energy requirements in a global scale and in the Indian context.

Evaluation of energy sources from the perspective of clean energy. Carbon equivalent

Module 2: **(9 Hours)**

Introduction to different types of energy storage and conversion devices and technologies. Synthesis and characterization of materials used for these technologies, Properties desired in the materials, Techniques to evaluate the properties and performance, failure modes and analysis,

Module 3: **(10 Hours)**

Environmental impact of the following technologies: Fuel cells, Batteries, Supercapacitors

Module 4: **(10 Hours)**

Environmental impact of Solar energy conversion devices, Wind, Mechanical Energy storage

Text Books:

1. Renewable Energy: Power for a Sustainable Future, Godfrey Boyle, Oxford University Press, 2004

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	2	2	1	1	-	3	2	-	2	-	3	2	-	2
CO2	3	3	2	2	2	3	1	-	2	-	3	3	2	3
CO3	2	2	2	2	2	3	2	-	2	-	3	2	2	3
CO4	3	3	3	3	2	3	2	-	2	-	3	3	3	3

Correlation Level 1: Slight 2: Moderate 3: High

Experimental Techniques in Materials Engineering			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Open Elective - III	Course Code:	MS4346

Course Objectives:

1. To study and apply optical microscopy and image analysis for microstructural evaluation.
2. To learn the principles and applications of X-ray diffraction and fluorescence in material characterization.
3. To explore electron microscopy techniques and related spectroscopy for detailed microstructural and compositional analysis.
4. To study advanced characterization tools for nanoscale imaging and thermal behavior analysis of materials.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Apply the principles of optical microscopy and image analysis techniques to evaluate microstructural features such as grain size, phase distribution, and inclusions.

CO2: Apply the fundamentals of X-ray diffraction and fluorescence to determine crystallographic structures, identify phases, and analyze elemental composition of materials

CO3: Analyze microstructural and compositional details of materials using advanced electron microscopy techniques including SEM, FESEM, and TEM, along with associated spectroscopic methods like EDX and WDS.

CO4: Evaluate material properties and behaviour using advanced characterization tools such as AFM, STEM, EELS, and thermal analysis techniques (DTA, DSC, TG), for nanoscale and thermal analysis applications.

Module 1: **(8 Hours)**

Optical Microscopy and Image analyzer: Understanding of image formation, resolution, numerical aperture, magnification, depth of field and depth of focus of a microscope. Quantitative and phase analysis (inclusion, size distribution etc.).

Module 2: **(10 Hours)**

X-ray diffraction and analysis: Production and properties of X-rays, X-ray diffraction, Structure factor and intensity calculations. Effect of texture, particle size, micro strain on diffraction lines. Indexing of powder photographs.

X-rays florescence: basics and applications in materials science.

Module 3: **(10 Hours)**

SEM and FESEM: Principle and applications, Modes of operation, Image formation - plane and fractured surfaces. Microanalysis (EDX, WDS etc.)

TEM: Principle and operation. Bright field and dark field images, Sample preparation techniques. Selected area diffraction, Reciprocal lattice and Ewald sphere construction, Indexing of selected area diffraction patterns.

Module 4: **(8 Hours)**

Advanced Characterization Techniques: STEM, AFM, Nanoindentation Testing, EELS-Principle and applications.

DTA/DSC-TG: Scope and applications in materials science.

Text Books:

1. B. D. Cullity, Elements of X-ray Diffraction (II edition), Addison-Wesley Publishing Co. Reading, USA, 1978.
2. P. J. Goodhew and F. J. Humphreys, Taylor and Francis, Electron Microscopy and Analysis, London, 2001(ISBN-0-7484-0968-8). Supplementary Readings: 1. S. H. Cohen and Marcia L. Lightbody (Editors), Atomic Force Microscopy / Scanning Tunneling Microscopy, Plenum Press, New York, 1994.
3. P. J. Haines (Editor), Principles of Thermal Analysis and Calorimetry Royal Society of Chemistry (RSC), Cambridge, 2002.
4. G. F. Vander Voort, Metallography: Principles and Practice ASM International, Materials Park, USA, 1984
5. S. Amelinckx, D. van Dyck, J. van Landuyt and G. van Tendeloo (Editors), Electron Microscopy: Principles and Fundamentals, VCH, Weinheim, 1997.
6. C. Suryanarayana and M. Norton, X-ray Diffraction, A Practical Approach, Plenum Press, New York, (1998).
7. Metallography and Microstructures, Metals Handbook, Volume 9, 9th edition, American Society for Metals, Metals Park, Ohio, 1986.
8. Materials Characterization, Metals Handbook, Volume 10, 9th edition, American Society for Metals, Metals Park, Ohio, 1986.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	1	3	3	1	1	1	1	-	2	3	3	2
CO2	3	3	2	3	3	2	2	2	2	1	3	3	3	3

CO3	3	3	2	3	3	2	2	2	2	1	3	3	3	3
CO4	3	3	2	3	3	2	2	2	2	1	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

8th Semester **Open Elective – III**

Non-Destructive Testing of Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Open Elective - III	Course Code:	MS4348

Course Objectives:

1. To introduce the principles, types, and applications of Non-Destructive Testing (NDT) methods.
2. To develop practical skills in Liquid Penetrant, Magnetic Particle, and Eddy Current Testing.
3. To learn and apply Radiographic and Ultrasonic Testing techniques for material evaluation.
4. To explore Acoustic Emission Testing for structural health monitoring and early defect detection.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Classify various Non-Destructive Testing (NDT) methods, including their principles, advantages, limitations, and applications.

CO2: Demonstrate proficiency in conducting and interpreting results from Liquid Penetrant Testing (PT), Magnetic Particle Testing (MT), and Eddy Current Testing (ET).

CO3: Apply Radiographic Testing (RT) and Ultrasonic Testing (UT) techniques to assess material integrity, ensuring safety and compliance with industry standards.

CO4: Utilize Acoustic Emission Testing (AET) for monitoring structural health and detecting early signs of material degradation.

Module 1: **(10 Hours)**

Introduction: Introduction to NDT, Classification of NDT processes; advantages and limitations of NDT

Eddy Current Testing and Liquid penetrant testing: Principle, Advantages, Limitations and applications of eddy current testing; Liquid penetrant testing - Principle, Advantages, Limitations and applications.

Module 2: **(8 Hours)**

Magnetic Particle Testing: Principle, Procedure, Magnetic media, Methods to generate magnetic fields, Method of De-Magnetization, Interpretation of indications, Advantages, limitations and applications.

Module 3: **(8 Hours)**

Radiographic Testing: Principle, Gamma radiography, X-ray radiography and Neutron radiography, Imaging modalities, Radiograph Interpretation, Precautions against radiation hazards.

Module 4: **(10 Hours)**

Ultrasonic Testing and Acoustic Emission Testing: Principles of ultrasonic testing, Ultrasonic propagation, Test techniques – normal and angle beam, Probes, Transducers, Applications, Advantages and limitations of ultrasonic testing.

Acoustic emission testing – principle, sources of acoustic emission, acoustic emission signal parameters, industrial applications

Text Books:

1. Practical Non-Destructive Testing, Baldev Raj, T. Jayakumar, M. Thavasimuthu, Narosa Publishing House, 2014.
2. Non-Destructive Testing Techniques, Ravi Prakash, New Age International Publishers, 1st revised edition, 2010.

Reference Books:

1. Non-Destructive Testing - Theory, Practice and Industrial Applications, Wong B Stephen, LAP Lambert Academic Publishing, USA, 1st edition, 2014.
2. Non Destructive Test and Evaluation of Materials, J. Prasad and C. G. K. Nair, Tata McGraw-Hill Education, 2011, 2nd edition.
3. ASM Metals Handbook, Non-Destructive Evaluation and Quality Control, American Society of Metals, Metals Park, Ohio, USA, Volume-17.
4. Charles, J. Hellier, Handbook of Non-destructive evaluation, Charles, J. Hellier, McGraw Hill, New York, 2001.
5. Paul E Mix, Introduction to Non-destructive testing: a training guide, Wiley, 2nd Edition New Jersey, 2005

CO-PO-PSO Mapping

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CO2	3	3	2	3	3	2	2	2	2	1	3	3	3	3
CO3	3	3	2	3	3	3	3	2	2	1	3	3	3	3

CO4	2	3	2	3	3	3	2	2	2	1	3	2	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

8th Semester **Open Elective – IV**

Functional Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Open Elective - IV	Course Code:	MS4350

Course Objectives:

1. To introduce the origin, classification, and processing of functional materials used in engineering.
2. To study structure-property relationships in magnetic, electronic, thermoplastic, and biomaterials.
3. To evaluate the role of functional materials in emerging technologies like EVs, batteries, fuel cells, and solar systems.
4. To apply microstructural analysis for characterizing ceramic-metal and composite functional materials.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the origin, classification, and processing methods of functional materials used in modern engineering applications

CO2: Analyze the structure-property relationships of various functional materials, including magnetic, electronic, thermoplastic, and biomaterials

CO3: Evaluate the application of functional materials in advanced technologies such as electric vehicles, batteries, fuel cells, and solar energy systems

CO4: Apply microstructural analysis to predict and characterize the effective properties of ceramic-metal and composite functional materials

Module 1: **(9 Hours)**

The Origin of Functional Materials (FMs), Potential Applications of FMs, Classification of FMs,

Processing Techniques: Powder Metallurgy Route, Melt-processing Route, Vacuum arc melting, Vacuum induction melting, Vapor deposition and types.

Module 2: **(9 Hours)**

Specific properties of functional materials: Magnetic materials, Electronic Materials and Sensors, Electric Contact Materials, Conducting Thermoplastics and polymer composites, Surface coatings for functional applications, Biomaterials and Shape memory metals, Invar alloys.

Module 3: **(8 Hours)**

Functional materials for electric vehicles, Li-ion and other battery materials, fuel cells, solar energy harvesting, Reflective and antireflective layers, Waste heat recovery materials,

Module 4: **(10 Hours)**

Microstructure-property correlations, characteristic dimensions and spatial variations, volume fraction, rules of mixture and effective field parameters; characterization of properties of FMs, macrostructural thermomechanical properties, effective material properties for ceramic-metal FMs, basic mathematical modelling.

Applications: Case studies on use of functional materials for various applications

Text Books:

1. Deborah D.L. Chung, Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications, World Scientific, 2010.
2. William F. Smith, Javad Hashemi, Foundations of Materials Science and Engineering, Mc Graw Hill Education, 2009.
3. D.D.L. Chung: Composite Materials- Functional Materials for Modern Technologies, Springer, 2002.
4. Hui-Shen Shen: Functionally Graded Materials - Nonlinear Analysis of Plates and Shells, CRC Press, 2009.
5. Y. Miyamoto, W.A. Kaysser, B.H. Rabin, A. Kawasaki, R.G. Ford (Eds): Functionally Graded Materials- Design, Processing and Applications, Springer, 1999.

CO-PO-PSO Mapping

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CO2	3	3	2	2	2	2	1	2	2	1	3	3	3	3
CO3	3	3	3	3	2	3	2	2	2	2	3	3	3	3
CO4	3	3	3	3	3	3	2	2	2	2	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

8th Semester **Open Elective – IV**

Composite Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Open Elective - IV	Course Code:	MS4352

Course Objectives:

1. To classify and characterize composite materials based on matrix and reinforcement types.
2. To apply micromechanical and macro-mechanical models for predicting composite properties.
3. To study manufacturing techniques for PMCs, MMCs, and CMCs with respect to processing and application needs.
4. To obtain knowledge on failure mechanisms and toughening strategies for designing durable composite materials.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Classify and characterize composite materials based on matrix and reinforcement types, and analyze their structural and functional roles in various applications.

CO2: Analyze and apply micromechanical and macro-mechanical models to predict the elastic and strength properties of composite materials, including the use of Halpin-Tsai equations and laminate theory.

CO3: Evaluate and select appropriate manufacturing techniques for polymer matrix composites (PMCs), metal matrix composites (MMCs), and ceramic matrix composites (CMCs), considering factors like matrix-reinforcement interface, processing conditions, and application requirements.

CO4: Assess the failure mechanisms and toughness enhancement strategies in composite materials, including crack deflection, fiber pull-out, and transformation toughening, to design durable composite structures.

Module 1: (10 Hours)

Introduction: definitions and classifications; natural composites; role of matrix and reinforcement; factors which determine properties; the benefits of composites. Reinforcements and the reinforcement matrix interface: natural fibers; synthetic organic fibers – aramid, polyethylene; and synthetic inorganic fibers – glass, alumina, boron, carbon,

silicon based fibers; particulate and whisker reinforcements, reinforcement-matrix interface – wettability, interfacial bonding, methods for measuring bond strength.

Metal matrix composites: Introduction, important metallic matrices; metal matrix composite processing: solid state processing – diffusion bonding, powder metallurgy; liquid state processing – melt stirring, compo-casting (rheocasting), squeeze casting, liquid infiltration under gas pressure; deposition – spray co-deposition and other deposition techniques like CVD and PVD; in situ processes. Interface reactions. Properties of MMCs – physical properties; mechanical properties like elastic properties, room temperature
strength and ductility, properties at elevated temperatures, fatigue resistance. Processing, structure of multi-filamentary superconductors, properties of aluminium reinforced with silicon carbide particles.

Module 2: **(10 Hours)**

Ceramic matrix composites: Introduction; processing and structure of monolithic materials– technical ceramics, glass-ceramics. Processing of ceramics: conventional mixing and pressing – cold pressing and sintering, hot pressing, reaction bonding processes, techniques involving slurries, liquid state processing – matrix transfer moulding, liquid infiltration, sol-gel processing, vapour deposition techniques like CVD, CVI, liquid phase sintering, lanxide process and in situ processes. Processing, properties and applications of alumina matrix composites - SiC whisker reinforced, zirconia toughened alumina; Glass ceramic matrix composites; Carbon-carbon composites - porous carbon-carbon composites, dense carbon-carbon composites.

Polymer matrix composites: Introduction; polymer matrices – thermosetting, thermoplastic, rubbers. Processing of PMCs: Hand methods – hand lay-up, spray-up methods; Moulding methods – matched die moulding, bag moulding processes (autoclave moulding), resin transfer moulding, pultrusion; Filament winding; Injection moulding. Processing, properties and applications of fibre-reinforced epoxies, PEEK matrix composites, rubber matrix composites. Damping characteristics. Environmental effects in polymer matrix composites. Recycling of PMCs.

Module 3: **(10 Hours)**

Composite structures: Sandwich structures, foam core type arrangements; Honey comb structures. **Micromechanics of unidirectional composites:** micromechanics models for stiffness – longitudinal stiffness, transverse stiffness, shear modulus, Poisson's ratio. Micromechanics models for strength – longitudinal tensile strength, longitudinal compressive strength, transverse tensile strength, transverse compressive strength, in plane shear failure, thermal and moisture effects.

Short fibre composites: reasons for using short fibre composites, fibre length, fibre orientation, stress and strain distribution at fibres, critical fibre length and average fibre stress, stiffness and strength: stiffness of aligned systems, non-aligned systems and variable fibre orientation, strength of aligned systems, 2-D composites, variable fibre orientation.

Module 4: **(06 Hours)**

Toughening mechanisms in composite materials: crack bowing, crack deflection, debonding, pull-out, wake toughening, microcrack toughening, transformation toughening.

Text Books:

1. Composite Materials Science and Engineering, K.K. Chawla, Springer
2. Composite Materials: Engineering and Science, by Matthews and Rawlings, CRC Press.

Reference Books:

1. An Introduction to Composite Material, by D. Hull and T.W. Clyne, Cambridge University press.
2. Metal Matrix Composites, Thermo Mechanical Behaviour by M. Taya, and R.J. Arsenault, Pergamon Press, Oxford.
3. Fundamentals of Metal Matrix Composites by S. Suresh, A. Martensen, and A. Needleman, Butterworth, Heinemann.

CO-PO-PSO Mapping

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CO2	3	3	2	3	2	2	1	2	2	1	3	3	3	3
CO3	3	3	3	2	2	3	2	2	2	2	3	3	3	3
CO4	3	3	3	3	2	3	2	2	2	2	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

METALLURGICAL AND MATERIALS ENGINEERING

List of Honours Subjects

Honours in Materials Engineering

Honours (Theory)

1. Physical Metallurgy of Metals and Alloys
2. Advanced Engineering Materials
3. Materials Selection and Design
4. Metallurgical Failure Analysis
5. Making and Metallurgy of Stainless Steels

Honours (Sessional)

1. Microstructural Analysis Laboratory
2. Metal and Powder Forming Laboratory

List of Minor Subjects

Minor in Industrial Metallurgy

Minor (Theory)

1. Introduction to Physical Metallurgy
2. Iron Making & Steel Making
3. Mechanical Metallurgy
4. Materials Characterization Techniques
5. Advanced Materials and Processing

Minor (Sessional)

1. Physical Metallurgy Laboratory
2. Materials Characterization Laboratory

Honours in Materials Engineering

5th Semester

Physical Metallurgy of Metals and Alloys			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Honours (Theory)	Course Code:	MS3175

Prerequisite:

Material Science and Engineering, Phase Transformation and heat treatment

Course Objectives:

1. To study phase diagrams and microstructural evolution of ferrous alloys and relate them to properties and applications.
2. To classify and analyze non-ferrous alloys, focusing on composition, processing, and heat treatment behaviour.
3. To evaluate the design and performance of nickel-based superalloys and other advanced engineering alloys.
4. To identify the properties and engineering applications of copper-based, precious, and rare metal alloys.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the phase diagrams and microstructural evolution of ferrous alloys, including steels and cast irons, and relate them to their mechanical properties and applications

CO2: Classify and analyze the composition, processing, and properties of key non-ferrous alloys such as aluminum, magnesium, and titanium, including their phase diagrams and heat treatment behaviour

CO3: Evaluate the design, strengthening mechanisms, and high-temperature performance of nickel-based superalloys and other advanced engineering alloys.

CO4: Identify and assess the characteristics and applications of copper-based alloys, lead, tin, zinc, babbitt metals, precious metals, and rare metals used in specialized engineering fields.

Module 1: **(9 Hours)**

Phase diagrams of Iron-cementite and iron-graphite system; microstructure and properties of different ferrous alloys - both steels and cast irons; types of cast iron, their microstructures and typical uses.

Common alloy steels; stainless steel, tool steel, high speed steel, high strength low alloy steel, microalloyed steel, specification of steels.

Module 2: **(9 Hours)**

Aluminium and its alloys: Classification and designation of Aluminum Alloys, Non-heat treatable, Wrought Aluminum Alloys, Heat treatable Wrought and Cast Aluminum Alloys, Al-Cu, Al-Zn, Al-Li, Al-Si alloys with their phase diagrams, Compositions, heat treatments, properties and applications.

Magnesium and its alloys: Classification of Magnesium Alloys, Wrought and Cast magnesium Alloys with their Phase Diagrams, Compositions, heat treatments, properties and applications.

Titanium and its alloys: Classification of Titanium Alloys, Compositions, heat treatments, properties and applications.

Module 3: **(9 Hours)**

Nickel and its alloys: Ni-Cr alloys, Ni-Al alloys, Ni-Cr-Al alloys, Ni-Cr-Al-Ti alloys Ni base super alloys phase diagram heat treatment properties and its Applications.

Introduction to super-alloys: Nickel base Super alloys, Strengthening mechanism of Ni base alloys (Solid-solution strengthening Precipitation strengthening, Carbide strengthening etc.,

Explanation of Anti-phase boundary energy, Lattice mismatch, Coarsening of gamma prime precipitates, Fe base super alloys and Co base super alloys new development, phase diagram alloying additions, properties, Advantages and disadvantages, Oxidation and corrosion resistance, long time phase stability.

Copper and its alloys: Copper-Zinc and Copper-Tin Phase Diagrams, Brasses and Bronzes Compositions, heat treatments, properties and applications.

Module 4: **(9 Hours)**

Lead, Zinc and Tin and their alloys: Compositions, heat treatments, properties and applications.

Babbitts (Antifriction alloys): Compositions, heat treatments, properties and applications.

Precious metals & their alloys: Silver, Gold, Platinum, Palladium & their alloys. Iridium, Osmium, Rhodium, Ruthenium & their electrical applications.

Rare metals and their alloys: Characteristics and mechanical properties of these alloys.

Text Books:

1. Physical Metallurgy Principles by Reed Hill
2. I J Polmear, Light Alloys, 5th Edition, Elsevier, 2017
3. Y Lakhtin, Engineering Physical Metallurgy, CBS Publishers, 1998.
4. Donald S Clark, Wilbur R Varney, Physical Metallurgy for Engineers, 2nd Edition, Van Nostrand Reinhold Company, 1989.
5. Sidney H Avner, Introduction to Physical Metallurgy, 2nd Edition, McGraw-Hill, 1997.

Reference Books:

1. Metals Handbook–Vol.2: Properties and Selection- Non-ferrous alloys and Pure Metals, ASM, 2014.
2. Charlie R Books, Heat Treatment- Structure and Properties of Non-ferrous Alloys, ASM,1982.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	2	2	1	-	1	-	3	3	3	2
CO2	3	3	2	2	2	1	-	-	1	-	3	3	3	2
CO3	3	3	3	2	2	2	-	-	1	-	3	3	3	3
CO4	3	3	2	2	2	2	-	-	1	-	3	3	3	2

Correlation Level 1: Slight 2: Moderate 3: High

6th Semester

Advanced Engineering Materials			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Honours (Theory)	Course Code:	MS3176

Prerequisite:

Material Science and Engineering

Course Objectives:

1. To study the development, structure, and properties of advanced materials like bulk metallic glasses.
2. To analyze thermodynamics, phase formation, and mechanical behaviour of high entropy alloys.
3. To study synthesis methods and electromagnetic properties of metamaterials for advanced applications.
4. To explore the structure and properties of quasicrystals and assess their technological relevance.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the need for and development of advanced engineering materials, including bulk metallic glasses, with emphasis on their structure, formation criteria, and functional properties.

CO2: Analyze the thermodynamic principles, phase formation rules, and mechanical behaviour of high entropy alloys to evaluate their performance in structural applications.

CO3: Evaluate the synthesis methods, unique electromagnetic properties, and application potential of metamaterials in advanced technologies.

CO4: Interpret the structure, symmetry, mechanical and magnetic properties of quasicrystals and other emerging advanced materials, and assess their suitability for specialized applications.

Module 1: **(10 Hours)**

Introduction: general introduction to material properties, requirements for materials with exotic properties, advances in materials development, new classes of advanced materials

Bulk Metallic glasses: Definition, Fundamental concepts, Types, Criteria for glass formation and stability, Mechanical and Functional properties, Processing microstructure and properties, Disadvantages, Examples, and Applications.

Module 2: **(9 Hours)**

High Entropy Alloys: Introduction, Definition, Thermodynamic concepts of HEAs/ Phase Formation Rules, Core effects, Microstructure and Mechanical Properties, Prediction of Structure and Phase Transformations.

Module 3: **(8 Hours)**

Metamaterials: Definition, Advantages over other materials, Types and synthesis, General Theory on Artificial Metamaterials, Experiments and Applications of Metamaterials.

Module 4: **(9 Hours)**

Quasicrystals: Definition, Introduction, structures and symmetries, Fundamental concepts, Quasicrystallography, Production, Defects, Elastic and Plastic Properties, Mechanical Properties, Magnetic Properties, Recent Developments, Applications. Any other relevant advanced materials.

Text Books:

1. Bulk Metallic glasses, C. Suryanarayana, A. Inoue, CRC Press, 2nd ed., 2017.
2. High-Entropy Alloys, B.S. Murty, J.W. Yeh, S. Ranganathan, Butterworth-Heinemann publications, 2014.
3. Metamaterials: Theory, Design, and Applications, Tie Jun Cui, David Smith, Ruopeng Liu, Springer US publications, 1st ed., 2010.
4. Quasicrystals: An Introduction to Structure, Physical Properties and Applications, J.B. Suck, M. Schreiber, P. Häussler, Springer-Verlag Berlin Heidelberg publications, 1st ed., 2002.
5. Fundamentals of Radiation Materials Science: Metals and Alloys, Gary S. Was, Springer International Publication, 2017.

Reference Books:

1. Bulk Metallic Glasses: An Overview, Michael K. Miller, Peter Liaw, Springer US publications, 1st ed., 2008.
2. High-Entropy Alloys Fundamentals and Applications, Michael C. Gao, Jien-Wei Yeh, Peter K. Liaw, Yong Zhang, Springer International Publishing Switzerland 2016.
3. Metamaterials: Physics and Engineering Explorations, Nader Engheta, Richard W Ziolkowski, Wiley-IEEE Press, 2006.
4. Quasicrystals, Volume 3, Takeo Fujiwara, Yasushi Ishii, Elsevier Science publications, 1st ed., 2007.
5. New Geometries for New Materials, Eric A. Lord, Alan L. Mackay, S. Ranganathan, Cambridge University Press, 2006.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	2	2	-	-	1	-	3	3	2	2
CO2	3	3	3	2	2	2	-	-	1	-	3	3	2	3
CO3	3	2	2	2	3	2	-	-	1	-	3	2	3	3
CO4	3	3	2	2	2	1	1	-	1	-	3	3	2	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

7th Semester

Materials Selection and Design			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Honours (Theory)	Course Code:	MS4179

Course Objectives:

1. To study the role and evolution of engineering materials in product design and development.
2. To learn and apply material selection methods considering design constraints and performance indices.
3. To evaluate material processing techniques with focus on shape compatibility, life-cycle, and environmental impact.
4. To integrate material properties, processing, and design strategies for optimizing product performance and sustainability.

Course Outcomes:

Upon successful completion of the course, students will be able to:

CO1: Analyze the role and evolution of engineering materials in design, including their properties and influence on the product development process.

CO2: Apply material selection methodologies (e.g., Ashby method) to analyze and choose appropriate materials considering design constraints, objectives, and performance indices.

CO3: Evaluate suitable material processing methods and their compatibility with product shapes and environmental impacts through life-cycle and eco-design considerations.

CO4: Analyze the integration of material properties, processing strategies, and industrial design aspects to optimize performance, cost, and sustainability in engineering products.

Module 1: (9 Hours)

Materials world and Design: Introduction to materials in design, Evolution of engineering materials and materials in products, Engineering materials and their properties,

Design process, types and tools of design, materials data for design, Analyzation of design product function, design Objective, constraints and free variables, steps of material selection in design process.

Module 2: **(9 Hours)**

Materials selection- Ashby method, material property charts, Materials selection strategy and procedure, material indices, materials selection procedure, the structural index, single and multiple constraints in material selection, conflicting objectives, Shape factors, limits to shape efficiency, Exploring material-shape combinations, Materials indices that include shape factors, Hybrid materials designing, composites, Sandwich structures, Cellular structures, Segmented structures.

Module 3: **(8 Hours)**

Materials processing: Processes classification and attributes, Processes selection steps, Material processes- shape relations, Processes selection screening and ranking,

Materials and environments: Materials life-cycle, Energy-consuming characteristic of materials, Eco-attributes of materials, Eco-selection of materials.

Module 4: **10 Hours)**

Materials and industrial design: The requirements pyramid, Product character and personality, Design considerations in the use of materials: quality control; selecting materials to optimize multiple properties; materials failure; long-term materials properties; materials behaviour under extreme conditions; corrosion; discussion of design and materials selection strategy; processing and process selection strategy; process economics; life-cycle thinking and eco-design; special topics.

Text Books:

1. M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Heinemann, 2005.
2. J. G. Gerdeen, H. W. Lord and R. A. L. Rorrer, Engineering Design with Polymers and Composites, Taylor & Francis, 2005.
3. D.R. Askeland and P.P. Phule, The Science and Engineering of Materials, Thomson Brooks/Cole Publication, 4th edition, 2006.
4. P. L. Mangonon, The Principles of Materials Selection and Design, Prentice Hall International, Inc., 1999.

Reference Books:

1. M.F. Ashby, Engineering Materials, 4th Edition, Elsevier, 2005.
2. ASM Metals Handbook, Vol.20- Materials Selection and Design, ASM, 1997.
3. M. F. Ashby and K. Johnson, Materials and Design, Butterworth Publication, 2002

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	-	-	2	-	-	2	-	3	3	2	2
CO2	3	3	3	2	2	2	-	-	2	-	3	3	3	3
CO3	3	2	3	2	2	3	-	-	2	-	3	3	3	3

CO4	3	3	3	2	2	3	-	2	2	2	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

7th Semester

Metallurgical Failure Analysis			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Honours (Theory)	Course Code:	MS4181

Course Objectives:

1. To introduce the objectives, stages, and methodologies of failure analysis in metallic components.
2. To classify different failure types and understand their fracture modes and stress conditions.
3. To apply analytical and testing techniques for identifying failure causes in materials.
4. To evaluate real-world failure cases and recommend preventive strategies based on root cause analysis.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the objectives, stages, and methodologies used in failure analysis of metallic components and structures.

CO2: Differentiate among various types of material failures such as ductile, brittle, fatigue, creep, corrosion, and wear, and identify the corresponding fracture modes and stress systems.

CO3: Apply appropriate testing and examination techniques—including fractography, SEM, and chemical analysis—to determine the cause of component failures

CO4: Evaluate failure case studies to diagnose root causes and recommend prevention strategies, considering factors like material properties, service conditions, heat treatment, and processing history.

Module 1: **(9 Hours)**

Aims of failure analysis, Principal factors in the premature failure of metallic components and Structures.

Stages of analysis: collection of background data & selection of samples, preliminary examination of failed part - visual examination and record keeping, non-destructive testing, mechanical testing, selection, presentation and cleaning of fracture surface, macroscopic examination of fracture surface, microscopic examination of fracture surface, scanning electron microscopy.

Tools and techniques in failure analysis.

Module 2: **(9 Hours)**

Types of failures: Ductile, brittle, fatigue, creep, corrosion, wear etc., Failure under creep and fatigue, creep fatigue interaction, life estimation under creep and fatigue.

Fracture modes: Shear mode, cleavage mode, other fracture modes, factors affecting the ductile-brittle relationship, stress systems related to fracture of ductile and brittle metals: Pure loading systems- Tension, Torsion, Compression, Bending and Fatigue. Effect of stress concentration, study of fractograph of metallic components.

Module 3: **(9 Hours)**

Determination of fracture type: Ductile and brittle fracture, failure due to Distortion, Fatigue, Creep, Wear, Corrosion, and Erosion. Elevated temperature failure, stress rupture failure and complex failure. Stress corrosion cracking, hydrogen embrittlement, liquid metal embrittlement, chemical analysis, simulated service testing.

Module 4: **(9 Hours)**

Mixed mode and fatigue failures, Failure mechanisms, Embrittlement phenomena, environmental effects, Failures due to faulty heat treatments, Failures in metal forming and welding Prevention of failures, Case studies in failure analysis, Case histories of component failures.

Text Books:

1. Fatigue of Materials, S. Suresh, Cambridge University Press, 2nd Edition, 1998.
2. Deformation and Fracture Mechanics of Engineering Materials, Richard W. Hertzberg, John Wiley & Sons, New York, 5th Edition, 2012.

Reference Book:

1. ASM Metals Hand Book, Failure Analysis and Prevention, Vol. 11, 10th Edition, ASM International, 2002.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO3	PO 4	PO 5	PO 6	PO 7	PO 8	PO9	PO1 0	PO1 1	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	2	-	2	-	2	-	3	3	2	2
CO2	3	3	2	2	2	-	-	-	2	-	3	3	3	2
CO3	3	3	2	3	3	-	-	-	2	-	3	3	3	2
CO4	3	3	3	3	3	2	2	2	3	2	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

8th Semester

Making and Metallurgy of Stainless Steels			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Honours (Theory)	Course Code:	MS4176

Course Objectives:

The main learning objective of this course is to prepare the students for:

1. Gaining a comprehensive knowledge on various aspects of Stainless steel making, metallurgy, Properties and its applications.
2. Acquiring knowledge on the classification of stainless steels and their properties.
3. Discussing the effect of how the composition and heat treatments affect the characteristics and corrosion behaviour of stainless steels.
4. Having a thorough knowledge on the numerous applications and importance of stainless steels.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1. Describe the essential elements responsible for the unique properties of stainless steels and basic metallurgical principles involved.

CO2. Classify the various types of stainless steels based on the microstructure and the effect of microstructure on the properties of stainless steels.

CO3. Explain the production methodology of stainless steel making and the influence of the process on the quality of the stainless steel.

CO4. Interpret the results of corrosion testing and PREN index and analyse the influence of the various environmental factors on the corrosion of stainless steels.

Module 1: **(12 Hours)**

History and Evolution of Stainless Steel

Essential elements, evolution, development of alloys, selection of Stainless steels, Recent processing enhancements. Some Metallurgical Principles.

Classification of Stainless Steels

Wrought and Cast Stainless steels – Ferritic, Martensitic, Austenitic, Cr-Ni-Mo Stainless steels, Precipitation Hardened, Duplex, Heat Resistant, Abrasive and Wear resistant

steels-Composition, Metallurgy, Properties, Phase Diagrams, Fretting and Galling, Welding and Weldability of Stainless steels.

Module 2: (9 Hours)

Melting and Secondary Refining of Stainless Steels

Raw Materials selection, Melting Furnaces (EAF, EIF), melt treatment, Continuous casting, secondary refining –AOD, VOD, IOC converters processing, advantages and limitations.

Module 3: (8 Hours)

Corrosion Behaviour of Stainless Steels

Atmospheric, aqueous, stress corrosion, cracking and Hydrogen Embrittlement, High Temperature corrosion, Corrosion of Cast stainless steels, PREN Index, Corrosion rate estimations- ASTM Practices.

Module 4: Applications of Stainless Steels (7 Hours)

Architecture and construction, Automotive and Marine systems, Petroleum, Chemical, Pulp and Paper Industries applications.

Text Books:

John C. Lippold, Damien J. Kotecki, "Welding Metallurgy and Weldability of Stainless steels", Wiley and Sons, Edition, 2005.

1. Jonathan Beddoes, J. Gordon Parr, "Introduction to Stainless Steels", ASM International, 2000.
2. Joseph R. Davis, "STAINLESS STEELS", ASM International, 3rd print, 1999.

Reference Books:

1. Donald Peckner, Irving Melvis Bernstein , "Hand Book of Stainless steels", McGraw Hill, 1977.
2. Joseph R. Davis, "Alloy Digest Source Book: Stainless Steels", ASM International, 2000.
3. Michael F. McGuire, "Stainless steels for Design Engineers", ASM International, 2008
4. R.A. Lula, James Gordon Parr , "Stainless steels", American Society for Metals, 1996.
5. Source book on Stainless steels, American Society for Metals, 1976.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PO1 0	PO11	PSO1	PSO 2	PSO3
CO1	3	2	-	-	-	-	-	-	-	-	2	3	1	1
CO2	3	2	-	-	-	1	-	-	-	-	2	3	2	1
CO3	3	3	2	2	2	2	-	-	1	1	2	3	2	3

CO4	2	3	2	3	3	3	1	-	2	-	2	3	3	2

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester

Microstructural Analysis Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Honours (Sessional)	Course Code:	MS3576

Course Objectives:

1. To train students in the preparation of metallographic samples for microscopic examination.
2. To study and interpret the microstructures of ferrous and non-ferrous metals and relate them to material properties.
3. To identify and differentiate types of cast irons based on microstructural features and processing effects.
4. To develop the ability to perform quantitative microstructural analysis.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Prepare the samples for microscopic examination

CO2: Analyse the microstructure of various ferrous and non-ferrous metals and alloys and explain the effect of the different phase constituents on the properties of the materials

CO3: Differentiate the different types of cast irons based on their morphology and analyse the effect of the processing on the microstructure.

CO4: Perform a quantitative analysis on any given microstructure.

List of Experiments:

(Minimum 08 experiments)

1. Study the working principle and operation of metallurgical microscope
2. Cold and hot mounting of specimens
3. Specimen preparation for metallographic observation
4. Macro etching - cast, forged and welded components.
5. Microstructural analysis of Plain carbon steels - low carbon, medium carbon, high carbon steels.
6. Microstructural analysis of cast irons - Gray, White, Malleable and Nodular types
7. Microstructural analysis of Austenitic Stainless steels and High-Speed Steels.
8. Microstructural analysis of non-ferrous alloys

9. Study the methods of grain size determination
10. Quantitative metallography of two-phase microstructures & image analysis
11. Microstructural analysis of welded joints.

Text Books:

1. Physical Metallurgy Laboratory Manual
2. Metallography Principles and Practice, George F. Vander Voort, ASM International, 1999.

Reference Books:

1. Metallography and Microstructures, ASM Handbook Volume 9, George F Vander Voort (Ed.), ASM International, 2004
2. Physical Metallurgy for Engineers, D. S. Clark and W. R. Varney, CBS Publications, New Delhi, 1st Edition, 1979.
3. Introduction of Physical Metallurgy, S. H. Avner, Mc Graw Hill, 2nd Edition, 1987.
4. Callister's Materials Science and Engineering, R. Balasubramaniam, Wiley India, 2014, 2ed.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	-	2	3	-	-	1	2	-	2	3	3	1
CO2	3	3	2	2	2	1	-	-	2	-	2	3	3	2
CO3	3	3	2	2	2	1	-	-	2	-	2	3	3	2
CO4	3	3	2	3	3	1	-	-	2	-	3	3	3	2

Correlation Level **1: Slight** **2: Moderate** **3: High**

7th Semester

Metal and Powder Forming Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Honours (Sessional)	Course Code:	MS4575

Course Objectives:

The main learning objective of this course is to prepare the students for:

1. Acquiring knowledge on basic metal forming processes by experimental study and analysis and by constructing formability diagrams
2. Reducing thickness by sheet metal rolling
3. Reducing the metal powders size and characterisation of metal powders
4. Producing green compacts and sintering the compacts.

Course Outcomes:

Upon completion the course, the students will be able to:

CO1: Demonstrate the formability behaviour of the metal forming process.

CO2: Examine the formability of different materials

CO3: Characterize the powders in terms of tap density, apparent density, flow rate and particle size

CO4: Make a compact of desired size and shape and compare the properties of the sintered compact with that of the green compact.

List of Experiments:

(Minimum 08 experiments)

1. Formability of sheet metal by Ericsson cupping test
2. Construction of Formability limit diagram
3. Diameter reduction in Wire drawing
4. Thickness reduction in Sheet metal rolling.
5. Study of Sheet metal forming using FEA analysis software
6. Powder size reduction by Ball Milling
7. Measurement of Flow rate, Apparent and Tap Density of Powders
8. Production of green compacts.

9. Density determination of sintered product.
10. Effect of Sintering temperature on the density of the sintered compact

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	2	1	-	1	2	-	2	3	2	3
CO2	3	3	2	2	2	1	-	-	2	-	2	3	3	3
CO3	3	3	-	3	3	-	-	-	2	-	2	3	3	2
CO4	3	3	2	2	3	1	-	1	2	-	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

Minor in Industrial Metallurgy

5th Semester

Introduction to Physical Metallurgy			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Minor (Theory)	Course Code:	MS3265

Course Objectives:

1. To learn about phase diagrams, alloying principles, and strengthening mechanisms in metallic systems.
2. To study phase transformations in steels using iron-carbon, TTT, and CCT diagrams.
3. To apply and evaluate heat treatment processes for improving steel properties.
4. To compare the composition, treatment, and applications of ferrous and non-ferrous alloys, including advanced alloys.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain binary and ternary phase diagrams, alloying principles, and strengthening mechanisms to explain the structure-property relationship in metallic systems.

CO2: Analyze the iron-carbon diagram and transformation diagrams (TTT and CCT), and analyze the influence of alloying elements on phase transformation behaviour in steels.

CO3: Apply suitable heat treatment processes (annealing, normalizing, hardening, tempering) and assess hardenability for enhancing the mechanical properties of steels.

CO4: Compare the composition, heat treatment, properties, and applications of various ferrous and non-ferrous alloys, including superalloys and shape memory alloys.

Module 1: **(9 hours)**

Phase diagrams – binary and ternary, principles of alloying, Hume-Rothery rules. Strengthening mechanisms – solid solution, work hardening, precipitation hardening, dispersion strengthening

Module 2: **(9 hours)**

Iron carbon diagram, isothermal, and continuous cooling transformation diagrams; influence of alloying elements on transformation characteristics

Module 3: **(5 hours)**

Heat treatment - annealing, normalizing, hardening and tempering of steels, hardenability

Module 4: **(12 hours)**

Introduction to important ferrous alloys (stainless and special steels, cast irons), aluminium alloys, titanium alloys, copper base alloys

Superalloys, shape memory alloys – classification, heat treatment, properties and applications

Text Books:

1. Physical Metallurgy: Principles and Practice, V. Raghavan, PHI Learning, Delhi, 2008.
2. Physical Metallurgy Principles, R. Abbaschian, R. E. Reed-Hill, Cengage Learning, 2009

Reference Books

1. Physical Metallurgy Vols. I, II, III, R.W. Cahn and P. Haasen, North Holland, 1996.
2. Light Metals, I.J. Polmear, Elsevier, 2005

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	1	2	-	-	-	1	-	2	3	2	-
CO2	3	3	2	2	2	-	-	-	-	-	2	3	3	-
CO3	3	3	3	2	2	1	-	-	1	-	2	3	3	2
CO4	3	2	3	2	3	1	-	1	2	1	2	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester

Iron Making and Steel Making			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Minor (Theory)	Course Code:	MS3266

Course Objectives:

1. To obtain knowledge about the blast furnace iron-making process, including raw materials, reactions, and operational advancements.
2. To study alternative iron-making methods and evaluate their industrial relevance.
3. To compare modern steelmaking techniques and understand the role of secondary refining.
4. To explore steel casting processes and review recent developments in the Indian iron and steel industry.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the blast furnace iron-making process, including raw material preparation, thermal and chemical reactions, slag control, and recent trends in blast furnace operations.

CO2: Describe the principles and processes of alternative iron-making methods, such as sponge iron production and smelting reduction, and evaluate their industrial significance.

CO3: Compare different modern steelmaking techniques (oxygen, electric arc, induction) and analyze the role of secondary steelmaking in refining steel quality.

CO4: Analyze various casting processes (ingot and continuous casting) for steel and assess the developments in the Indian iron and steel industry over the past decade.

Module 1: **(11 hours)**

Introduction: Blast Furnace Route for Iron Making, The Blast Furnace and its accessories, The burden and its preparation, Physical – Thermal and Chemical process in a Blast Furnace, Blast Furnace slag and its control, Control of hot metal composition, Blast Furnace plant and Accessories, Modern trends in Blast Furnace practice, Control of irregularities in the blast furnace, Performance of Blast Furnace over the years.

Module 2: **(8 hours)**

Alternative Methods: Need for alternative Methods, Sponge Iron production by using solid and gaseous reductants, Smelting Reduction Processes;

Module 3: **(10 hours)**

Modern Steel Making: Different routes of steelmaking. Oxygen Steelmaking: Top and Bottom blown converter processes, Hybrid processes. Electric Steel making: Electric Arc furnaces, Induction furnaces. Secondary Steelmaking;

Module 4: **(7 hours)**

Casting of liquid steel: Ingot Casting of Steel, Continuous Casting of Steel;

Iron and Steel Scenario in India in the last decade.

Text Books:

A. Ghosh and A. Chatterjee: Ironmaking and Steelmaking Theory and Practice, Prentice-Hall of India Private Limited, 2008.

1. Dipak Mazumdar, "A First Course in Iron and Steel Making", Universities press – IIM, Series in Metallurgy and Materials Science, India, 2015.
2. Tupkary, R. H. &Tupkary V.R., "An Introduction to Modern Iron Making", Khanna Publishers, 4th edition, 2016, "An Introduction to Modern Steel Making", Khanna Publishers, New Delhi, 2000.

Reference Books:

1. A.K. Biswas: Principles of Blast Furnace Iron making, SBA Publication,1999.
2. D.H. Wakelin (ed.): The Making, Shaping and Treating of Steel (Iron making Volume), The AISE Steel Foundation, 2004.
3. R.J. Fruehan (ed.): The Making, Shaping and Treating of Steel (Steel making Volume), The AISE Steel Foundation, 2004.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	1	2	1	-	-	2	-	1	3	2	2
CO2	3	2	2	1	2	1	-	-	2	-	1	3	2	3
CO3	3	3	3	1	3	1	-	-	2	1	2	3	3	3
CO4	2	2	2	1	2	2	1	-	3	1	2	3	3	2

Correlation Level **1: Slight** **2: Moderate** **3: High**

7th Semester

Mechanical Metallurgy			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Minor (Theory)	Course Code:	MS4269

Course Objectives:

1. To study elastic and plastic deformation behaviour and the role of dislocations in material deformation.
2. To explore various strengthening mechanisms and their effects on mechanical properties.
3. To interpret mechanical test results and analyze material behaviour under different loading conditions.
4. To evaluate failure mechanisms such as fracture, fatigue, and creep for predicting material performance.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the elastic and plastic behaviour of materials and explain the role of dislocations in deformation, multiplication, and interaction with obstacles.

CO2: Analyze various strengthening mechanisms such as grain boundary, solid solution, precipitation, and martensitic strengthening, and their influence on mechanical properties.

CO3: Interpret the results of mechanical tests (tension, compression, and impact), and evaluate stress-strain behaviour, strain aging, and transition temperature phenomena.

CO4: Assess the failure mechanisms of materials under fracture, fatigue, and creep, and predict material performance under various loading and environmental conditions.

Module 1: **(9 hours)**

Introduction: Elastic and plastic behaviour of materials, Concept of stress and strain, Important Mechanical Properties.

Dislocation Theory: Imperfections in Solids, Concept of dislocations, Edge, Screw and mixed dislocation, Burger Vector, Stress field around dislocation; Dislocation Movement, Dislocation Glide and climb, Force acting on dislocations, Core of the dislocation and the Peierls Stress, Nabarro stress, Energy of dislocations, Forces between Dislocations, dislocation and plastic strain, Dissociation or Combination of Dislocations, Dissociation

Criterion, Glide plane of dislocation, Dislocation-Precipitate Interactions, Frank-Read Source:

Dislocation Multiplication, Dislocation Pile-ups.

Module 2: **(8 hours)**

Strengthening Mechanisms: Types of strengthening mechanisms, Grain boundary strengthening, Hall-Petch Relation, Hall-Petch strengthening limit, Strengthening from second phase, Factors influencing second-phase particle strengthening, Solid Solutions strengthening, Precipitation Hardening, Precipitation Sequence-GP Zones, Factors affecting precipitation hardening, Interaction between particles and dislocations-Particle Cutting and Orowan mechanism, Coherent and Incoherent Precipitates, Fibre Strengthening, Martensitic strengthening.

Module 3: **(9 hours)**

Tension Test: Elastic and plastic deformation, Time Independent and time dependent Deformation, Tension

Test Setup and specimens, Typical Stress strain diagram and properties derived from it, Elastic strain recovery, Instability in tension, necking criterion, Yield Point Phenomenon, Strain Aging, Dynamic strain ageing, Holloman power curve, Factors affecting shape and magnitude of stress-strain curve.

Compression Test: Needs of compression test, Compression Test Setup and specimens, Behaviour of ductile and brittle materials in Compression, Barrelling.

Impact Testing: The brittle failure problem and notch sensitivity, notched bar impact test; Significance and

Specialized test for transition temperature; Metallurgical factors affecting transition temperature; Temper Embrittlement.

Module 4: **(10 hours)**

Introduction to Fracture: Elementary theories of fracture. Griffiths theory of brittle fracture, ductile fracture.

Introduction to Fatigue Testing: Significance of fatigue test, stress cycles, S-N curve, fatigue limit,

mechanism of fatigue failure, effect of stress concentration, size, surface condition and environments on fatigue, effect of metallurgical variables on fatigue properties.

Introduction to Creep Testing: The creep curve, creep properties of metals. Stress-rupture test, deformation and fracture at elevated temperature, theories of creep, Prediction of long time properties, Creep resistant materials, Effect of metallurgical variables on creep.

Text Books:

1. George E. Dieter, Mechanical Metallurgy, McGraw Hill, New York, 3rd Edition, 1986. (ISBN 0-07-016853-8) TA405.D53
2. Norman E. Dowling, Mechanical Behavior of Materials, Prentice-Hall, Upper Saddle River, New Jersey, 2nd Edition, 1999. (ISBN0-13-905720-X)
3. Derek Hull and D.J. Bacon: Introduction to Dislocations, Pergamon Press, 2008.

Reference Books:

1. Thomas H. Courtney, Mechanical Behaviour of Materials, McGraw Hill, New York, 2nd Edition, 2000. (ISBN0-07-028594-2) TA405.C859
2. William F. Hosford, Mechanical Behaviour of Materials, Cambridge University Press 2005
3. MA Meyers and K Chawla, Mechanical Behaviour of Materials, Prentice Hall
4. David Broek, Elementary Engineering Fracture Mechanics, Martinus Nijhoff Publishers, Hingham, Massachusetts, 3rd Edition, 1984. (ISBN 90-247-2656-5)
5. Richard W. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, John Wiley & Sons, New York, 3rd Edition, 1989. (ISBN 0-471-63589-8) TA417.6H46
6. Donald Peckner (editor) The Strengthening of Metals, Reinhold Publishing, New York, 2nd Edition, 1967.

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	3	2	2	2	-	-	-	2	-	2	3	3	2
CO2	3	3	2	2	2	-	-	-	2	-	2	3	3	2
CO3	3	3	2	3	3	-	-	-	2	-	2	3	3	2
CO4	3	3	2	3	3	2	1	-	2	-	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

7th Semester

Materials Characterization Techniques			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Minor (Theory)	Course Code:	MS4271

Course Objectives:

1. To introduce the principles and applications of optical and electron microscopy.
2. To explain the fundamentals of X-ray diffraction for material characterization.
3. To analyze material behaviour using thermal analysis techniques.
4. To develop the ability to select appropriate characterization methods for microstructural and compositional analysis.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Describe the principles of optical and electron microscopy.

CO2: Explain the principles of XRD for materials characterization.

CO3: Analyse thermal reactions using thermal analysis data.

CO4: Select a suitable characterization technique for microstructural and compositional analysis of materials.

Module 1: **(8 hours)**

Microscopy: Introduction to optical microscope, concepts of magnification, resolution, numerical aperture, depth of field, principles of image formation, DIC illumination, Hot stage microscopy, advantages and limitations.

Module 2: **(9 hours)**

Electron microscopy, SEM and TEM, electron source, sample preparation, electron specimen interaction, lens arrangement, mode of imaging, bright field image, dark field image, image contrast, SAD. Comparison of OM, SEM and TEM. Advantages, limitations.

Module 3: **(9 hours)**

X-Ray diffraction: Properties of X-rays, X-Ray diffraction methods, Intensities of diffracted beam and structure factor, phase mixtures and phase diagram, determination of crystal structure, Phase identification.

Module 4: **(10 hours)**

Surface characterization techniques: EDS, WDX, XRF, XPS and AES, and EPMA.

Thermal analysis techniques: TGA, DSC, DTA and TMA

Text Books:

1. Materials Characterization Techniques, S Zhang, L. Li and Ashok Kumar, CRC Press, 2008.
2. David B. Williams, C. Barry Carter, Transmission Electron Microscopy, Textbook for Materials Science, Springer, 2009, 2nd Edition.
3. An Introduction to Material Characterization, Khangaonkar P R, Penram Intl. Publishing (India) Pvt. Ltd, Mumbai, 2010.
4. Elements of X-Ray Diffraction, B.D. Cullity and S.R. Stock, 3rd Edition, Prentice Hall, NJ, 2001.
5. ASM Handbook, Vol.10, Materials Characterization, ASM International, USA, 1998.

Reference Books:

1. Scanning electron microscope (SEM) instrumentation: Scanning Electron Microscopy and X-Ray
2. Microanalysis. Springer, Goldstein JI, Newbury DE, Michael JR, Ritchie NW, Scott JH, Joy DC New York, NY, 2018, 4th Edition.
3. Practical of Electron Microscope in material science: Electron Diffraction in the Electron Microscope- J. W. Edington, (Philips Technical Library) Macmillan Education UK (1975)
4. Practical of Electron Microscope in material science: J Interpretation of Transmission Electron Micrographs - J. W. Edington, (Philips Technical Library) Macmillan Education UK (1975)

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	3	-	-	-	2	-	2	3	3	2
CO2	3	2	2	2	3	-	-	-	2	-	2	3	3	2
CO3	3	3	2	3	3	-	-	-	2	-	2	3	3	2
CO4	3	3	3	3	3	-	-	-	2	-	2	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

8th Semester

Advanced Materials and Processing			
Hours/Week L-T-P:	3-0-0	Credits:	3
Course Type:	Minor (Theory)	Course Code:	MS4266

Course Objectives:

1. To study the structure, properties, and applications of advanced alloy systems like aluminum, titanium, superalloys, and shape memory alloys.
2. To obtain knowledge about the synthesis and characteristics of advanced composites, intermetallics, and ceramic compounds.
3. To analyze the formation and properties of nanocrystalline, amorphous, and quasicrystalline materials.
4. To explore advanced processing techniques for the development of novel engineering materials.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Explain the structure, properties, and applications of advanced alloy systems such as high-strength aluminum alloys, titanium-based alloys, superalloys, and shape memory alloys.

CO2: Describe the characteristics and synthesis of advanced composite materials, intermetallics, and ceramic compounds, including aluminides, silicides, borides, nitrides, and carbides.

CO3: Analyze the synthesis methods, structure, and unique properties of nanocrystalline, amorphous (metallic glasses), and quasicrystalline materials.

CO4: Evaluate advanced materials processing techniques such as rapid solidification, laser surface modification, mechanical alloying, rapid prototyping, and self-propagating high-temperature synthesis for developing novel materials.

Module 1: **(10 hours)**

Advanced Al Alloys: High temperature and high strength Al alloys such as Al-FeV-Si, nanocrystalline Al alloys, etc.;

Ti based Alloys: Advances in Ti based Alloys;

Superalloys: Ni base and Co base superalloys;

Shape Memory Alloys: physical metallurgy, properties, etc.;

Module 2: **(8 hours)**

Advanced Composites: in situ composites, nanocomposites, etc.;

Intermetallics; Aluminides, Silicides, borides, Nitrides and Carbides.;

Module 3: **(9 hours)**

Nanocrystalline Materials: Synthesis, Structure and Properties.:

Amorphous Materials; Metallic glasses, Glass forming ability, Thermodynamics and kinetics of glass formation, Bulk Metallic Glasses, Properties; Quasicrystalline Materials; Structure, Synthesis, Properties;

Module 4: **(9 hours)**

Advanced Processes: Rapid solidification processing, Laser surface Modification, Mechanical Alloying, Rapid prototyping, Self propagating High temperature synthesis, inert gas condensation etc.

Text books:

1. Light Alloys: from traditional alloys to nanocrystal by I. J. Polmiar, Elsevier/Butterworth Heinemann.
2. Titanium and Titanium alloys by C. Leyens and M. Peters, Wiley-VCH
3. The Superalloys: Fundamentals and Applications, by Roger C. Reed, Cambridge Univ. Press, 2008.
4. Ultra fine grained steels by Yuqing Weng, Springer.
5. Introduction to Nanomaterials, Charles Poole and Frank Owens, Wiley 2007
6. Bulk Metallic Glasses: an overview by Michael Miller and Peter Liaw, Springer.
7. Bulk Metallic glasses, C. Suryanarayana, A. Inoue, CRC Press, 2nd ed., 2017.
8. Quasicrystals: An Introduction to Structure, Physical Properties and Applications, J.B. Suck, M. Schreiber, P. Häussler, Springer-Verlag Berlin Heidelberg publications, 1st ed., 2002.

Reference Books:

1. Bulk Metallic Glasses: An Overview, Michael K. Miller, Peter Liaw, Springer US publications, 1st ed., 2008.
2. High-Entropy Alloys Fundamentals and Applications, Michael C. Gao, Jien-Wei Yeh, Peter K. Liaw, Yong Zhang, Springer International Publishing Switzerland 2016.
3. Quasicrystals, Volume 3, Takeo Fujiwara, Yasushi Ishii, Elsevier Science publications, 1st ed., 2007.
4. Nanomaterials Nanotechnologies and Design – D.L. Schodek, P. Ferreira, M.F. Ashby, Butterworth-Heinemann, 2009

CO-PO-PSO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2	PSO 3
CO1	3	2	2	2	2	2	-	-	2	-	2	3	2	3
CO2	3	2	2	2	2	2	-	-	2	-	2	3	3	3
CO3	3	3	2	2	3	2	-	-	2	-	3	3	3	3
CO4	3	3	3	3	3	2	1	-	2	-	3	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

6th Semester

Physical Metallurgy Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Minor (Sessional)	Course Code:	MS3566

Course Objectives:

1. To construct crystal structure models and demonstrate atomic packing, linear, and planar densities.
2. To develop skills in preparing metallic samples for microstructural observation.
3. To examine and differentiate microstructures of ferrous and non-ferrous alloys, including steels and cast irons.
4. To measure grain size and phase volume fractions through quantitative microstructural analysis.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Demonstrate the atomic packing efficiency, linear and planar densities by constructing crystal structure models.

CO2: Prepare metallic samples for microstructural observation.

CO3: Examine the microstructures of ferrous and non-ferrous alloy samples and distinguish the microstructures of steels and cast irons.

CO4: Determine the grain size and volume fractions of phases in the given microstructure.

List of Experiments:

(Minimum 08 experiments)

1. Preparation and study of crystal structure models
2. Study the working principle and operation of metallurgical microscope
3. Cold and hot mounting of specimens
4. Specimen preparation for metallographic observation
5. Study the Fe-Fe3C phase diagram
6. Microstructural analysis of low, medium and high carbon steels
7. Microstructural analysis of cast-iron specimens
8. Microstructural analysis of non-ferrous alloys
9. Study the methods of grain size determination

10. Quantitative metallography of two-phase microstructures

Text Books:

1. Physical Metallurgy Laboratory Manual
2. Metallography Principles and Practice, George F. Vander Voort, ASM International, 1999.

Reference Books:

1. Metallography and Microstructures, ASM Handbook Volume 9, George F Vander Voort (Ed.), ASM International, 2004
2. Physical Metallurgy for Engineers, D. S. Clark and W. R. Varney, CBS Publications, New Delhi, 1st Edition, 1979.
3. Introduction of Physical Metallurgy, S. H. Avner, Mc Graw Hill, 2nd Edition, 1987.
4. Callister's Materials Science and Engineering, R. Balasubramaniam, Wiley India, 2014, 2nd. Edition.

CO-PO-PSO Mapping

CO	**PO 1**	**PO2**	**PO 3**	**PO 4**	**PO 5**	**PO6**	**PO 7**	**PO 8**	**PO 9**	**PO1 0**	**PO11**	**PSO 1**	**PSO 2**	**PSO 3**
CO1	3	2	2	2	2	-	-	2	2	-	2	3	2	2
CO2	3	2	2	3	3	-	-	2	2	-	2	3	3	2
CO3	3	3	2	3	3	-	-	2	2	-	2	3	3	3
CO4	3	3	2	3	3	-	-	2	2	-	2	3	3	3

Correlation Level **1: Slight** **2: Moderate** **3: High**

7th Semester

Materials Characterization Laboratory			
Hours/Week L-T-P:	0-0-3	Credits:	1.5
Course Type:	Minor (Sessional)	Course Code:	MS4565

Course Objectives:

1. To develop proficiency in using optical and electron microscopy for microstructural and fractographic analysis.
2. To analyze elemental composition and phase distribution using SEM-EDS techniques.
3. To conduct X-ray diffraction for structural analysis, including lattice parameters and crystallite size determination.
4. To evaluate thermal behaviour of materials using TGA, DTA, and DSC techniques.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Demonstrate the use of optical and scanning electron microscopy techniques for detailed microstructural and fractography analysis of materials.

CO2: Analyze elemental composition and phase distribution in materials using SEM-EDS and interpret results accurately.

CO3: Perform X-ray diffraction experiments to identify crystal structures, measure lattice parameters, determine crystallite size, and quantify lattice strain.

CO4: Evaluate the thermal behaviour of materials through techniques such as TGA, DTA, and DSC to understand oxidation kinetics and thermal transitions.

List of Experiments:

(Minimum 08 experiments)

1. Image analysis of microstructures using OM.
2. Microstructural analysis using SEM.
3. Fractography analysis using SEM.
4. Chemical analysis of phases using SEM-EDS.
5. Determination of crystal structures, lattice parameter measurements, indexing and
6. identification of phases using X-Ray Diffractometer
7. Determination of lattice strain and crystallite size using X-Ray Diffractometer
8. Oxidation kinetics using TGA / DTA.

9. Determination of thermal properties using DSC

Text Books:

1. Materials Characterization Techniques, S Zhang, L. Li and Ashok Kumar, CRC Press, 2008.
2. David B. Williams, C. Barry Carter, Transmission Electron Microscopy, Textbook for Materials Science, Springer, 2009, 2nd Edition.
3. An Introduction to Material Characterization, Khangaonkar P R, Penram Intl. Publishing (India) Pvt. Ltd, Mumbai,2010.
4. Elements of X-Ray Diffraction, B.D. Cullity and S.R. Stock, 3rd Edition, Prentice Hall, NJ, 2001.
5. ASM Handbook, Vol.10, Materials Characterization, ASM International, USA, 1998.

Reference Books:

1. Materials Characterization Techniques Laboratory Manual.

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CO2	3	3	2	3	3	-	-	2	2	-	2	3	3	2
CO3	3	3	2	3	3	-	-	2	2	-	2	3	3	3
CO4	3	2	2	3	3	-	-	2	2	-	2	3	3	3

Correlation Level 1: Slight 2: Moderate 3: High