

AY 2019-20 ONWARDS

## Course Structure and Curriculum

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*Master of Technology in Metallurgical and Materials  
Engineering  
(Specialization: Industrial Metallurgy)*



**DEPARTMENT OF METALLURGICAL & MATERIALS ENGINEERING  
VEER SURENDRA SAI UNIVERSITY OF TECHNOLOGY, ODISHA,  
BURLA – 768018**

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*Syllabus for M. Tech in Industrial Metallurgy, Department of Metallurgical and Materials Engineering, Veer Surendra Sai University of Technology (VSSUT) Odisha*

## **Vision**

To be recognized as a center of excellence in education and research in the field of Metallurgical and Materials Engineering,so as to be the terminus for students, researchers and faculties for the pursuit of academic excellence, technical innovation, and industrial professionalsfor socio-economic upliftment of society to meet the global challenges.

## **Mission**

Metallurgical and Materials Engineering Department of VSSUT Burla strives to achieve global excellence in education and research and preparing students for global competitiveness by fostering educational excellence through:

- M1:** Maintaining state of the art academic and research facilities by keeping up with the technological advancement to provide quality technical education for analysis, design and operation of metallurgical and materials systems.
- M2.** Fortifying collaboration with world class R&D organizations, national and international institutes, universities and industries and alumni for continuous evolution in teaching, research and consultancy practices to contribute in the national mission programs.
- M3.** Providing the students with academic environment of excellence, leadership, ethical guidelines so as tostimulate to pursue life-long learning by enhancing knowledge and skills for professional advancement.

## **Program Educational Objectives (PEOs)**

PEO1: To acquire competency in solving real-life problems and to design/develop sustainable and cost-effective products/solutions according to the prevailing industrial challenges and socio-economic context.

PEO2: To create a congenial environment that promotes learning, growth and imparts ability to work with inter-disciplinary groups in professional, industry and research organizations by applying engineering and material science principles.

PEO3: To demonstrate effective communication skill, ability to draw relevant conclusions for scholarly writing and presentation, professional attitude and a desire to learn.

### **Program Specific Outcomes (PSOs)**

PSO1: The students will be able to understand, model and solve problems related to industrial metallurgy by applying engineering knowledge and management practices so as to offer techno-commercially feasible and socially acceptable solutions.

PSO2: The students will be effective communicator, aspire to learn and be able to handle problems with professional attitude so as to lead a successful career in industries or entrepreneurial endeavors or undertake research in broad area of industrial metallurgy, independently as well as in group.

### **Program Outcomes (POs)**

PO1: Ability to independently carry out research/investigation and development work to solve practical problems pertaining to Metallurgical and Materials Engineering systems.

PO2: Ability to write and present a substantial technical report/document

PO3: Ability to demonstrate a degree of mastery over Metallurgical and Materials Engineering domain to further comprehend and inculcate Industrial Metallurgy related issues.

PO4: Ability to apply techniques, skills and modern engineering tools to design, conduct, analyze and interpret experimental data for relevant engineering practices.

PO5: To identify, formulate, design and offer techno commercially feasible and socially acceptable solutions to real life engineering problems in order to address the prevailing safety hazards, material degradation, sustainability and environmental pollution in metallurgical industries.

PO6: Ability to practice professional ethics, demonstrate a capacity for self-management/teamwork and recognize the need for self-improvement through continuing education by involving in life-long learning.

### **Mission and PEO Mapping**

<b>Mission</b>	<b>M1</b>	<b>M2</b>	<b>M3</b>
<b>PEO 1</b>	<b>3</b>	<b>3</b>	<b>1</b>
<b>PEO 2</b>	<b>3</b>	<b>3</b>	<b>3</b>
<b>PEO 3</b>	<b>1</b>	<b>2</b>	<b>3</b>

**1: Slight (Low)**

**2: Moderate (Medium)**

**3: Substantial (High)**

## Course Structure and Detailed Syllabus

### SEMESTER I

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	Core-1	MMMIM101	Phase Transformation and Heat treatment	3	0	0	3
2	Core-2	MMMIM102	Advanced Thermodynamics and Kinetics of Engineering Materials	3	0	0	3
3	PE-1	MIMPE101	Advanced Joining Technology	3	0	0	3
		MIMPE102	Introduction to Nano Materials	3	0	0	
		MIMPE103	Metal Forming Technology	3	0	0	
4	PE-2	MIMPE104	Modelling and Simulation of Materials	3	0	0	3
		MIMPE105	Numerical Methods in Material Engineering	3	0	0	
		MIMPE106	Diffusion in Solids	3	0	0	
5	Common		Research Methodology & Intellectual Property Rights	3	0	0	3
6	Lab-1	MMMIM103	Industrial Metallurgy Lab-I (Phase Transformation and Heat Treatment Laboratory)	0	0	3	2
7	Lab-2	MMMIM104	Industrial Metallurgy Lab-II (Modeling and Simulation Laboratory)	0	0	3	2
8	Audit-1	MCAC1001	English for Research Paper Writing	0	0	0	0
		MCAC1002	Disaster Management				
		MCAC1004	Value Education				
<b>Total Credits</b>							19

### SEMESTER II

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	Core-3	MMMIM201	Advanced concept in steel Technology	3	0	0	3
2	Core-4	MMMIM202	Characterization of Materials	3	0	0	3
3	PE-3	MIMPE201	Extraction of Metals	3	0	0	3
		MIMPE202	Advanced Concept in Iron Making	3	0	0	
		MIMPE203	Advanced Casting Process	3	0	0	
4	PE-4	MIMPE204	Advanced Composite Material	3	0	0	3
		MIMPE205	Thermomechanical Engineering	3	0	0	
		MIMPE206	Ceramic materials	3	0	0	
5	Common		Minor Project/Research Seminar	3	0	0	2
6	Lab-1	MMMIM203	Industrial Metallurgy Lab-III (Powder Metallurgy and composite Laboratory)	0	0	3	2
7	Lab-2	MMMIM204	Industrial Metallurgy Lab-IV (Material Characterization Laboratory)	0	0	3	2
8	Audit-2	MCAC2001	Constitution of India	0	0	0	0
		MCAC2002	Pedagogy Studies				
		MCAC2004	Personality Development through Life Enlightenment Skills.				
<b>Total Credits</b>							18

<b>SEMESTER III</b>							
<b>Sl. No.</b>	<b>Core/ Elective</b>	<b>Subject Code</b>	<b>Subject Name</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>Credits</b>
1	PE-5	MIMPE301	Physics of Metal	3	0	0	3
		MIMPE302	Environmental Degradation and Corrosion				
		MIMPE303	Surface Engineering and Coating Technology				
2	OE-1	MIMOE301	Material Recycling and Waste management	3	0	0	3
		MIMOE302	Advanced Material				
		MIMOE303	X-ray electron and Microscopy				
3	Minor Project		Dissertation (Phase-I)	0	0	20	10
<b>Total Credits</b>							16

<b>SEMESTER IV</b>							
<b>Sl. No.</b>	<b>Core/ Elective</b>	<b>Subject Code</b>	<b>Subject Name</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>Credits</b>
3	Major Project		Dissertation (Phase-II)	0	0	3 2	16
<b>Total Credits</b>							16

<b>Subject Code: MMMIM101</b>	<b>Phase Transformations and Heat Treatment</b>
Pre-Requisite:	Co-requisite:
Module -I	[08]
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; Kirkendall effect; Effect of pressure and temperature on diffusivity.	
Module -II	[08]
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 -III	[08]
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. Martensitic transformations in non-ferrous alloy systems.	
Module -IV	[08]
Review of 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 -V	[ 08]
Heat treatment of steels: Austenitization, 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.	
<b>TEXT BOOK(S):</b>	
1.	Phase Transformations in Metals and Alloys by D. A. Porter and K. E. Easterling, CRC Press.
2.	Phase Transformations in Materials by R. C. Sharma
<b>REFERENCE BOOK(S):</b>	
1.	Solid State Phase Transformations by Raghavan, PHI.
2.	Heat Treatment by Rajan and Sharma, PHI.

<b>COURSE OUTCOMES:</b> <i>After successful completion of this course, students will be able to:</i>	
CO1	Develop enhanced critical thinking, analytical and problem-solving skills in materials science and engineering based on concepts of metallurgical thermodynamics and kinetics.
CO2	Demonstrate the basic principles underlying liquid to solid and solid-state phase transformations in a range of materials.
CO3	Evaluate the microstructural transformations in the material after different thermal and thermochemical treatments.
CO4	Evaluate and select an optimal material with/without heat treatment, with/without surface hardening, and with/without surface protection necessary to ensure the required product life.
CO5	Incorporate different manufacturing technologies and heat treatments in product, device and system design and planning.

**Course Articulation Matrix**

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

**Program Articulation Matrix row for this Course**

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	2	3	3	3

Subject Code: MMMIM102		Advanced Thermodynamics & Kinetics of Engineering Materials	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Introduction to thermodynamics & kinetics, thermodynamics system, phase equilibrium of single and two component system, concept of state and path functions, First, second, and third law of thermodynamics and applications to Nano Scale Systems.		
Module -II		[08]	
	Hess's Law, Kirchhoff's law, Entropy and its classification, Entropy calculation for multi-component systems, Statistical interpretation of entropy, Boltzmann equation, Concept of micro- and macrostate, Ensemble, Auxiliary Functions – Maxwell's Equations, Gibbs – Helmholtz Equation, Concept of standard state.		
Module -III		[08]	
	Kinetics theory of gases, rate of reaction, Molecularity and order of a reaction, rate controlling step, Kinetics of Topo-chemical reactions, Gibbs phase rule and its application in different type's chemical reactions, Concept of Gibbs free energy, calculation of free energy for different kinds of systems, Richardson- Ellingham diagram and its utility in metallurgical processes.		
Module -IV		[08]	
	Thermodynamics of multi-component alloy systems, Free energy – composition diagrams for binary alloy systems.		
Module -V		[08]	
	Determination of liquidus, solidus and solvus lines, Activity of solution, Gibbs Free energy calculation of solution, Gibbs-Duhem equation, Thermodynamics of defects.		
TEXT BOOK(S):			
1.	Introduction to the Thermodynamics of Materials by D.R. Gaskell; Taylor and Francis.		
2.	Kinetics of Metallurgical Reactions by H.S. Ray; Oxford and IBH Publishing Co.		
REFERENCE BOOK(S):			
1.	Advanced Thermodynamics for Engineers by Winterbone		
2.	Advanced Thermodynamics Engineering by Kalyan Annamalai, Ishwar K. Puri, Milind A. Jog		
COURSE OUTCOMES: <i>After successful completion of this course, students will be able to:</i>			
CO1	To evaluate the modern thermodynamic models for description of chemical reaction and phase transformation in materials.		
CO2	To demonstrate reaction kinetics and stability criteria of different metals on the basis of its energy content and temperature.		
CO3	To analyse and implement the thermodynamic laws in day-to-day applications.		
CO4	To analyse and express the kinetics of the mass transport in solids including the process of surface and interfaces.		
CO5	To work independently with the literature in search, choice and checking of correctness of the necessary information and mathematical expressions.		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	3	2	2	2

Subject Code: MIMPE101		Advanced Joining Technology	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Introduction: Manufacturing and Joining Fundamental Mechanisms of joining, heat and pressure in joining Classification of joining processes, Heat generation and power density concept in welding Protection of the weld metal approaches, effect of gases on weld properties, Principle of fusion welding processes, oxy-fuel gas welding.		
Module -II		[08]	
	Fundamentals of welding: type of weld, types of joint, welding position, arc heat generation Physics of welding arc: arc initiation, maintenance, shielded metal arc welding Electrode melting rate, effect of electrode polarity and welding parameters Gas tungsten arc welding: electrode, shielding gases.		
Module -III		[08]	
	Variants of Gas tungsten arc welding: GTAW, Hot wire GTAW, Flux assisted GTAW, Variants of Gas metal arc welding: Pulse GMAW, CMT welding ,Submerged arc welding Electro-slag and Electro-gas welding processes Laser beam welding, Brazing Soldering and Braze welding, Fundamentals of resistance welding Resistance welding processes: spot, seam welding, Flash butt welding, Adhesive joining, Welding bonding, Solid state joining technologies: Fundamentals Ultrasonic joining, Diffusion bonding, Explosive welding, Magnetic pulse welding.		
Module -IV		[08]	
	Weld thermal cycle, Heat affected zone and weld thermal cycle: I, Heat affected zone and weld thermal cycle: II, Solidification of weld metal, Fundamentals of Weldability of metals, Weldability of carbon & alloy steels: Fe-C, CCT, Weldability of stainless steels: schaeffler diagram, Metallurgical transformation in weld and heat affected zone of steels.		
Module -V		[08]	
	Weldability of aluminium alloys: porosity, HAZ softening, PMZ issues, Solidification cracking and their control, Residual stresses in weld joints: effect on joint performance, and control of residual stress, Cracking of welded joints: solidification and liquation cracks, Cracking of welded joint: cold cracking		
TEXT BOOK(S):			
1.	Sindo Kou “Welding Metallurgy,2nd Edition, John wiley and sons		
2.	Lancaster, J. F.,”Metallurgy of Welding” Springer		
REFERENCE BOOK(S): <i>After successful completion of this course, students will be able to:</i>			
1.	Advanced Joining Technologies by T.H. North		
2.	Advanced Joining Processes by Lucas F M Da Silva & Mohamad S El-Zein & Paulo Martins		
COURSE OUTCOMESS: <i>After successful completion of this course, students will be able to:</i>			
CO1	Express welding processes based on different industrial and commercial requirements.		
CO2	Compile gas and electric arc welding processes and their use in the field of engineering.		
CO3	Demonstrate weld joints and its failure conditions and provide suitable solutions.		
CO4	Develop the concept of welding metallurgy for best weld structures in real life applications.		

CO5	Demonstrate the importance of alternative joining processes required in materials processing.
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**Course Articulation Matrix**

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

**Program Articulation Matrix row for this Course**

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	1	2	1

Subject Code: MIMPE102		Introduction to Nano Materials	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Introduction: Emergence of Nanotechnology, Bottom-Up and Top-Down Approaches Challenges in Nanotechnology, Surface Energy, Chemical Potential as a Function of Surface Curvature		
Module -II		[08]	
	Electrostatic Stabilization Synthesis of metallic nanoparticles, Nanoparticles through Homogeneous Nucleation, Synthesis of oxide nanoparticles, Synthesis of semiconductor nanoparticles, Core-Shell Nanoparticles		
Module -III		[08]	
	Lithography, Assembly of Nanoparticles and Nanowires, Physical Properties of Nanomaterials, Electrical conductivity, Applications of Nanomaterials		
Module -IV		[08]	
	Characterization of Nano materials by: SEM, XRD, TEM, SPM		
Module -V		[08]	
	Special Nanomaterials 6.1. Introduction 6.2. Carbon Fullerenes and Nanotubes, Micro and Mesoporous Materials, Over view of Nanocomposites and Nanograined Materials		
TEXT BOOK(S):			
1.	Guozhong Cao, "Nanostructures and Nanomaterials, synthesis, properties and applications", Imperial College Press, 2004.		
2.	Yury Gogotsi, "Nanomaterials – Handbook", CRC Press, Taylor & Francis group, 2006		
REFERENCE BOOK(S):			
1.	Nanomaterials: An Introduction to Synthesis, Properties and Applications by Dieter Vollath		
2.	Introduction to Nanoscience and Nanomaterials By (author): Dinesh C Agrawal		
COURSE OUTCOMES: After successful completion of this course, students will be able to:			
CO1	Incorporate the ideas for production of different types of nano materials		
CO2	Solve different problems associated with processing of nano materials		
CO3	Characterize different nano material using various advanced techniques such as TEM and XRD.		
CO4	Evaluate the properties of nano materials for a suitable application from its		
CO5	Demonstrate different machine used for characterization of nano materials		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	2	3	3	2	1

Subject Code: MIMPE103		Metal Forming Technology	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Forming – fundamentals, classification, flow stress, flow curves, effect of parameters such as strain rate, temperature etc., workability, anisotropy, Deformation zone geometry, friction, residual stress. Theoretical analysis (theory of plasticity), Stress-strain relationship, Strain hardening, Material incompressibility, Work of plastic deformation, Work hardening, Yield criteria, Flow rule, Yield criterion and flow rule for Anisotropic material, Initiation and extent of plastic flow- Problems.		
Module -II		[08]	
	Forging, calculation of forging loads, forging defects, powder metallurgy forging, residual stresses in forgings. Rolling, classification of rolling process, hot rolling, cold rolling, forces and geometrical relationships in rolling, Rolling load calculation, defects in rolled products, theories of hot rolling and theories of hot rolling, Torque and power.		
Module -III		[08]	
	Extrusion, Analysis of extrusion process, hydrostatic extrusion, Production of seamless pipe and tubing. Wire and Tube Drawing, analysis of tube drawing, residual stresses in rod, wire and tube. Sheet metal forming, deep drawing, Forgeability, effect of various factors, definitions. Selection of equipment, die design, parting line, flash, draft, tolerance. Defects, causes and remedies.		
Module -IV		[08]	
	High velocity forming methods, superplastic forming, hydroforming, isothermal forging. Principles and processes. FLD and LDR, CAD, CAM in forming use of software like OPTRIS, DEFORM, etc. Workability. Lubricants in rolling, forging, extrusion, wire drawing, sheet metal forming. Tool design		
Module -V		[08]	
	Sol-gel and other processes for powders. Slip casting, extrusion injection moulding, HIP and CIP (Isostatic pressing), sintering. Blow moulding, Blow and Injection Moulding. Compression and transfer Moulding, Pultrusion. Filament Moulding. Resin Transfer Moulding.		
TEXT BOOK(S):			
1.	Mechanical Metallurgy, S.I. Metric edition, George E. Dieter, McGraw Hill Book Company.		
2.	Metal Forming: Mechanics and Metallurgy by William F. Hosford and Robert M. Caddell, PTR Prentice- Hall (USA).		
REFERENCE BOOK(S):			
1.	Surender Kumar, Technology of Metal Forming Processes, Prentice - Hall, Inc., 2008.		
2.	Henry S. Valberg, Applied Metal Forming - Including FEM Analysis, Cambridge University Press, 2010.		
COURSE OUTCOMES: After successful completion of this course, students will be able to:			
CO1	Apply the concept of plastic deformation for metals and alloys to convert them in to useful shapes for intended engineering applications		

CO2	Select an appropriate forming process to manufacture a component.
CO3	Design different metal forming equipment
CO4	Design different sheet metal working processes
CO5	Estimate formability limits for sheets and bulk metals.

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	3	2	2	1

Subject Code: MIMPE104		Modelling and Simulation of Materials	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Introduction to the computational approach to Materials Science and Engineering: Model classification. Basic modeling procedure. Classification of materials science processes and physical phenomena. Length scales and the corresponding modeling techniques.		
Module -II		[08]	
	Diffusion based phenomena: Mass and Heat transfer by diffusion. Various systems where these are important. Basic heat and mass transfer differential equations. Their formulation into discretized algebraic equations and solution using Finite Difference Method. Analyzing the effect of various kinds of boundary conditions.		
Module -III		[08]	
	Microstructure modeling - Macro-scale (Spinodal decomposition): Quasi-chemical model of solutions, nucleation versus spinodal mechanisms of phase separation, Cahn-Hilliard equation as a modification of classical diffusion equation with the inclusion of gradient energies, spectral implementation for numerical solutions of Cahn-Hilliard equation.		
Module -IV		[08]	
	Microstructure modeling - Molecular-scale - Calculating diffusivities/mobilities: Mechanisms of diffusion, vacancy diffusion in substitutional solid solutions, Molecular dynamics (MD) simulations, constant temperature MD simulations, vacancy diffusion in forced Lennard-Jones system using constant temperature MD		
Module -V		[08]	
	Mechanical behavior - Dislocation dynamics: Looking at plastic deformation as a result of collective behaviour of dislocation motion and interactions. Simulating dislocation dynamics as a function of orientation.		
TEXT BOOK(S):			
1.	K. M. Hangos and I. T. Cameron, "Process Modeling and Model Analysis", Academic Press:London, 2001.		
2.	R. Aris, "Mathematical Modelling Techniques", Dover:New York, 1994.		
REFERENCE BOOK(S):			
1.	Numerical Modeling in Materials Science and Engineering by Rappaz, Michel, Bellet, Michel, Deville, Michel		
2.	Modeling and Simulation for Material Selection and Mechanical Design edited By George E. Totten, Lin Xie, Kiyoshi Funatani		
COURSE OUTCOMES: <i>After successful completion of this course, students will be able to:</i>			
CO1	Identify different modelling technique in material science.		
CO2	Apply heat and mass transfer equation in a physical process.		
CO3	Recognize microstructural modelling in a macroscale.		
CO4	Comprehend microstructural modelling in a microscale.		
CO5	Simulate dislocation behavior.		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	1	3	1	3

Subject Code: MIMPE105		Numerical Methods in Material Engineering	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Sources of errors, Approximation and Errors in computing: Introduction, Significant digits, Inherent error, Rounding error, Truncation error, Absolute and relative error, Error propagation.		
Module -II		[08]	
	Roots of non-linear Equations and solution of system of Linear Equations: Bisection method, False position Method, Newton-Raphson Method, fixed – point iteration, Muller’s method for complex and multiple roots, convergence of Bisection, Newton- Raphson’s and False position methods, Gauss Elimination method by pivoting, Gauss – Jordan method, Iterative methods: Gauss-Jacobi and Gauss - Seidel methods, Relaxation method.		
Module -III		[08]	
	Difference Operators & Interpolation: Forward and Backward difference operators and table, Interpolation with equidistant point, Lagrange Interpolation Polynomial, Newton Interpolating Polynomial using divided Difference Table.		
Module -IV		[08]	
	Numerical Differentiation and Integration: Differentiating continuous functions, differentiating tabulated functions, Higher order derivatives, Richardson’s Extrapolation, Newton – cotes integration formula, Trapezoidal rule, Simpson’s rule.		
Module -V		[ 08]	
	Numerical Solution of Ordinary and Partial Differential Equations: Taylor series method, Euler and modified Euler method, Runge Kutta methods, Finite differences approximations of partial derivatives.		
TEXT BOOK(S):			
1.	B.S. Grewal, "Numerical Methods in Engineering & Science", Khanna Publication, Ed. 9th.		
2.	Santosh K. Gupta: Numerical Methods for Engineers, New Age International (P) Limited, New Delhi, 1998.		
REFERENCE BOOK(S):			
1.	Numerical Methods for Engineers by Steven C. Chapra and Raymond P. Canale		
2.	Numerical Methods for Engineers by D. Vaughan Griffiths and I.M. Smith		
COURSE OUTCOMESS: <i>After successful completion of this course, students will be able to:</i>			
CO1	To analyze and control the errors of approximation in large-scale numerical calculations.		
CO2	To demonstrate and incorporate the numerical techniques to find the roots of nonlinear equations and solution of system of linear equations.		
CO3	To become capable of handling large system of equations, non - linearities, and complicated geometries that are not uncommon in engineering practice		
CO4	Analyze and demonstrate the difference operators and the use of Interpolation.		
CO5	To solve the numerical solutions of ordinary and partial differential equations by means of numerical Differentiation and Integration.		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	3	2	3	3

<b>Subject Code: MIMPE106</b>	<b>Diffusion in Solids</b>
Pre-Requisite:	Co-requisite:
Module -I	[08]
Thermodynamics and defects in solids: Concept of free energy, enthalpy and entropy, Gibb's free energy change with temperature in a single component system, Thermodynamic parameters in a binary system Thermodynamics and phase diagrams, Concept of the chemical potential and the activity of elements, Point defects, Equilibrium vacancy concentration in a pure element, Equilibrium concentration of interstitial atoms, Defects in the ordered phases, Calculation of thermodynamic parameters.	
Module -II	[08]
Fick's laws: Fick's laws of diffusion and thin film solution, Solution in semi-infinite diffusion couples (error function analysis), Solution for homogenization (separation of variables).	
Module -III	[08]
Diffusion under chemical potential gradient, the composition profiles in an inter diffusion zone and diffusion as a tool to make products: Diffusion under the thermodynamic driving forces, Driving force for diffusion and Fick's laws of diffusion, Product phase formations because of diffusion in real systems, Diffusion process as a tool to make products, Definition and description of different diffusion terms.	
Module -IV	[08]
Interstitial diffusion, Concept of random walk, Substitutional diffusion, Activation energy for diffusion, Orientation dependence, Diffusion in the ordered phase.	
Module -V	[08]
Determination of different kinds of diffusion parameters: Matano-Boltzmann analysis, Calculation of diffusion parameters using the Matano-Boltzmann analysis, Den Broeder and Wagner's approach, Problem of finding the initial contact plane, Effect of molar volume in a hypothetical diffusion couple, The Kirkendall effect, The intrinsic diffusion coefficients, Darken analysis and the van Loo relation, Integrated diffusion co-efficient, Calculations of the integrated diffusion coefficients, Tracer diffusion coefficient and the vacancy wind effect, Recent developments on the Kirkendall effect.	
<b>TEXT BOOK(S):</b>	
1.	Diffusion in Solids by Shewmon Paul G.
2.	Diffusion in Solids by Helmut Mehrer
<b>REFERENCE BOOK(S):</b> <i>After successful completion of this course, students will be able to:</i>	
1.	Diffusion in crystalline solids by Graeme E. Murch and Arthur S. Nowick
2.	Diffusion in Bulk Solids and Thin Films: Some Phenomenological Examples by Devendra Gupta
<b>COURSE OUTCOMES:</b>	
CO1	Describe the role of diffusion in materials.
CO2	Solve basic problems involving steady-state and non-steady-state diffusion phenomena.
CO3	Express the driving forces for solid-state diffusion and the application of such knowledge to

	materials design and engineering materials processing.
CO4	Analyze the Matano-Boltzmann analysis and its implications for materials properties and performance.
CO5	Apply the knowledge of diffusion in solids for various metallurgical processes

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	3	2	3	3

<b>Subject Code: Common</b>		<b>Research Methodology &amp; Intellectual Property Rights</b>	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
Module -II		[08]	
Module -III		[08]	
Module -IV		[08]	
Module -V		[ 08]	
<b>TEXT BOOK(S):</b>			
1.			
2.			
<b>REFERENCE BOOK(S):</b>			
1.			
2.			
<b>COURSE OUTCOMESS:</b>			
CO1			
CO2			
CO3			
CO4			
CO5			

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1						
CO2						
CO3						
CO4						
CO5						

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course						

Subject Code: MMMIM103		Industrial Metallurgy Lab-I (Phase Transformation and Heat Treatment Laboratory)	
Pre-requisite:	None	Co-requisite:	None
<b>LIST OF EXPERIMENTS</b>			
1.	Measurement of volume fraction, surface area in two phase and single-phase materials.		
2.	To study the Recovery, Recrystallization and Grain growth behavior of given material.		
3.	To study the phase transformation of Pb-Sn eutectic alloy using DSC.		
4.	Draw the cooling curves of Pb-Sn alloy with the help of DTA.		
5.	To study the precipitation Hardening behavior mechanism in Al-alloys.		
6.	Nucleation of Ice from Water: A Modelling Approach.		
7.	Study of nucleation and growth in Eutectoid steel.		
8.	To study the surface hardening treatments like carburizing/Boronizing on steels.		
COURSE OUTCOMES: <i>At the end of this course, students will demonstrate the ability to:</i>			
CO1	Define the role of phase transformations on the development of microstructure and properties of metallic materials.		
CO2	Evaluate and analyze the microstructures resulting from near-equilibrium vs. far-from-equilibrium thermal treatments.		
CO3	Write the necessary steps required to heat treat ferrous and non-ferrous materials.		
CO4	Create new methodologies to produce heat treatment steps to relate properties with microstructure of the materials.		
CO5	Express the fundamental principles that determines the evolution of structures from liquid melt as well as diffusional processes.		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	2	3	3	3

(Subject Code: MMMIM104)		Industrial Metallurgy Lab-II (Modeling and Simulation Laboratory)	
<b>Pre-requisite:</b>	None	<b>Co-requisite:</b>	None
<b>LIST OF EXPERIMENTS</b>			
1.	MATLAB programme to plot the first four Eigen functions of a one – dimensional rectangular potential well with infinite potential barrier.		
2.	Numerical solution of the Schrodinger wave equation for a rectangular potential well with infinite potential barrier using MATLAB programme.		
3.	Toy model in molecular electronics: IV characteristics of a single level molecule		
4.	Determine the lattice constant and lattice angles for atomically resolved STM image of HOPG (Highly Oriented Pyrolytic Graphite using offline Scanning Probe Imaging Processor (SPIP) Software.		
5.	To determine the surface roughness of raw and processed AFM images of glass, silicon and films made by different methods using offline SPIP software.		
6.	Simulation of I-V Characteristics for a single Junction circuit with a single quantum Dot using MOSES 1.2 Simulator		
<b>COURSE OUTCOMESS:</b> <i>At the end of this course, students will demonstrate the ability to:</i>			
CO1	Analyze a problem with proper identification and assign the appropriate computer programme to solve metallurgical crisis		
CO2	Apply different types of simulation techniques to solve real life problem.		
CO3	Comprehend the utility of different software tools in solving real time problems and day to day problems		
CO4	Develop skills to apply simulation software to handle industry problems with confidence		
CO5	Develop knowledge on utilizing simulation tools for research application		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	1	3	1	3

Subject Code: MMMIM201		Advanced concept in steel Technology	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Introduction to steel: classification of steels over view, carbon steels, alloy steel, effect of alloying elements on steel properties, difference between steel and cast iron, steel vs other nonferrous alloys, important application in automotive, construction and power sectors, strengthening mechanism in steels, phases in steels over view.		
Module -II		[08]	
	Steel making practice over view: history of steel making practices, general layout of steel making plant LD, Electric arc, BOP, OBM, Hybrid process, Slag basicity and fluidity, refractory linings. Steel making practice over view: history of steel making practices, general layout of steel making plant LD, Electric arc, BOP, OBM, Hybrid process, Slag basicity and fluidity, refractory linings.		
Module -III		[08]	
	Secondary steel making processes like steel degassing, and steel cleaning, De-oxidation practice, inclusions in steel.		
Module -IV		[08]	
	Advance casting process over view: Thin slab casting, near net shape casting continuous casting vs conventional casting, heat treatment over view: normalising, annealing, hardening, tempering,		
Module -V		[ 08]	
	Destructive testing over view like tensile test, charpy impact test, fatigue test, creep test, wear test, problems face by steel industries, further developments in steel industries, surface treatment over view, anodising, galvanisation, aluminising.		
<b>TEXT BOOK(S):</b>			
1.	Iron and steel making theory and practice book by Ahindra Gosh and Amit Chatterjee.		
2.	Steel making by AK Chakraborty		
<b>REFERENCE BOOK(S):</b>			
1.	First Course in Iron and Steel Making by Dipak Mazumdar		
2.	Steel making by AK Chakraborty.		
<b>COURSE OUTCOMESS:</b> <i>After successful completion of this course, students will be able to:</i>			
CO1	Incorporate the ideas for development of new generation of steel		
CO2	Solve different problems associated with processing of steel		
CO3	Demonstrate the equipment used for mechanical testing of steel		
CO4	Evaluate the properties of steel for a suitable application from its composition and processing steps		
CO5	Apply the knowledge for protecting the steel from different environment		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	2	3	3	2	2

Subject Code: MMMIM202		Characterization of Materials	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Introduction to materials characterization & its importance, Fundamentals of Crystallography, levels of characterization (macro, meso and micro), Resolution, depth of field/focus, aberrations (spherical, chromatic and astigmatism) and its remedial measures.		
Module -II		[08]	
	Optical microscopy (OM) – Microscope construction and working, reflected/transmitted light microscope, theoretical and practical resolution of optical microscope, numerical aperture, principle of image formation, effective/empty magnification, Types of illumination - bright field, dark field, polarized light and phase contrast, applications of each type of illumination. Sample preparation for optical microscopy, features of an image.		
Module -III		[08]	
	Introduction to scanning electron microscope (SEM), working and construction, advantages/disadvantages as compared to OM, types of electron gun and comparison between them. Electron - specimen interaction, imaging modes (secondary and backscattered), effect of spot size, apertures, accelerating voltage on SEM image, Everhart-Thornley detector, Robinson detector, solid state segmented detector, atomic number and topological contrast. Chemical analysis using SEM, EDS/WDS working principle, construction, resolution of EDS/WDS detector, advantages/disadvantages.		
Module -IV		[08]	
	X-ray diffraction: Generation of X-rays, characteristic X-ray spectrum, Bragg's Law, Diffraction methods: Laue method, rotating crystal method, powder method, structural factor, applications of X-ray diffraction in materials characterization: determination of crystal structure, lattice parameter.		
Module -V		[08]	
	Thermal analysis techniques & its Importance, principles and applications of differential thermal analysis (DSC), differential scanning calorimetry (DSC) and thermo gravimetric analysis (TGA). Brief idea of TEM: principle of operation, application. Introduction to advanced microscopic techniques.		
TEXT BOOK(S):			
1.	Materials Characterization by Yang Leng, - 2nd Edition, Wiley-VCH Verlag GmbH & Co.		
2.	Microstructural Characterization of Materials- D. Brandon and W.D. Kaplan, John Wiley and Sons, 2008.		
REFERENCE BOOK(S): <i>After successful completion of this course, students will be able to:</i>			
1.	Goodhow P.J., J. Humhreys, R. Beanland, Electron Microscopy & Analysis Taylor and Fransis publication		
2.	Krishna, R., Ananthraman T.R., Pande C.S., Arora, O.P., Advanced Techniques for Microstructural Characterization (ed), Trans Tech Publication		
COURSE OUTCOMESS:			
CO1	Characterize the structures and chemistries of materials using traditional analytical experimental techniques		

CO2	Select the proper characterization techniques to solve problems in research and/or industry
CO3	Comprehend the basic microscopy images of materials
CO4	Identify the basic spectra of materials characterizations and can characterize the chemical composition of materials.
CO5	Correlate processing, microstructure, properties and performance analysis.

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	1	3	2	1

<b>Subject Code: MIMPE201</b>	<b>Extraction of Metals</b>
Pre-Requisite:	Co-requisite:
Module -I	[08]
Overview of Extractive Metallurgy processes; Pyro-metallurgy, Hydrometallurgy and Electrometallurgy; Thermodynamic Principles of metal extraction; Ellingham diagrams, Free energy Concept.	
Module -II	[08]
Ellingham diagrams for oxides, Sulphides and Chlorides. Kinetic Principles: Activation energy concept, Hydrogenation reaction, leaching of oxide sulphide ore, leaching kinetics.	
Module -III	[08]
Solvent extraction and ion exchange, chemical precipitation and gaseous reduction.	
Module -IV	[08]
Concept of activity, chemical potential in metal extraction, slag basicity, sulphide capacity, Henry's law, Raoult's law and oxidation potential of slag.	
Module -V	[ 08]
Electrode potentials, Electro Chemistry, Law of electrolysis, Current density, fused salt and aqueous salt electrolysis, series and parallel connection.	
<b>TEXT BOOK(S):</b>	
1.	Principles of Extractive Metallurgy: A. Ghosh & H.S. Ray, IIN Publications, Kolkata 1984.
2.	Principles of Extractive Metallurgy: Rosenquist, T., McGrawhill-Kogakusha International – 1983
<b>REFERENCE BOOK(S):</b>	
1.	Gilchrist J.D., Extraction Metallurgy, Pergamon.
2.	Newton J., Extractive Metallurgy, Wiley
<b>COURSE OUTCOMESS:</b> <i>After successful completion of this course, students will be able to:</i>	
CO1	Draw and analyze flow sheet of process route for a given ore.
CO2	Apply the basic thermodynamics, electrode, and kinetics principles involves in metal extraction.
CO3	Organize the different requirements for smelting operation and their subsequent incorporation.
CO4	Demonstrate the use of various diagrams such as Ellingham diagram, predominance diagram in diverse unit processes.
CO5	Evaluate different mathematical problems related to pyro, hydro, electro-metallurgy.

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	2	3	3	1

Subject Code: MIMPE202		Advanced Concept in Iron Making	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	History of Iron making in India, Indian and other resources of raw materials required for iron making. coke making. Blast furnace plant and -Modern blast furnace, plant layout, Details of construction of blast furnace and its main accessories; gas cleaning system, hot blast generation. Blast furnace refractories and blast furnace cooling system.		
Module -II		[08]	
	Agglomeration of iron ore fines, sintering and pelletisation, evaluation of properties of blast furnace, burden materials and application to blast furnace performance. Blast furnace plant operation, blowing in, blowing out and banking of blast furnace, role of burden charging and distribution in iron extraction, irregularities in Blast furnace operation and their remedies. Blast furnace products their quality control and disposal, coke rate and fuel efficiency of B.F. operations.		
Module -III		[08]	
	Modern trends in Blast furnace practice-Production of super flux sinter, pellets, super flux and cold bonded pellets. Auxiliary fuel injection in the blast furnace. High temp. blast, humidified and oxy generated blast, high top pressure, Desulphurization of hot metal. Chemical processes in Blast Furnace, Reactions in Tuyere, hearth and bosh zone.		
Module -IV		[08]	
	Reduction and coke gasification, Reactions in stack and exit gases. Thermodynamics of Blast furnace process requirement in Blast furnace, temp. profile in the furnace. Free energy and equilibrium consideration in Blast furnace a brief discussion on blast furnace stoichiometry and enthalpy balance.		
Module -V		[08]	
	Present and future prospects of Alternate route for iron making, concept of direct reduced iron (DRI), low shaft furnace and electro thermal processes of iron making. Direct reduction processes, their classification, characteristics of raw materials, Smelting reduction processes. Difficulties in Alternate routes of iron making processes, uses of DRI and scrap in steel making.		
TEXT BOOK(S):			
1.	Modern Iron Making - Dr. R.H. Tupkary		
2.	Principles of Blast Furnace iron making - Dr. A K Biswas		
REFERENCE BOOK(S):			
1.	Basic Concepts of Iron and Steel Making by Sujay Kumar Dutta, Yakshil B. Chokshi		
2.	Beyond the Blast Furnace, CRC Press, 1994.		
COURSE OUTCOMESS: <i>After successful completion of this course, students will be able to:</i>			
CO1	Incorporate the ideas for designing new furnaces and new technology		
CO2	Solve different problems associated with production of iron		
CO3	Analyze selection of cheaper substitute of iron production.		
CO4	Evaluate the essential raw materials required for production of iron in a cheaper way		

CO5	Apply their knowledge for producing a high quality output with high production rate
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Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	2	3	3	2	2

Subject Code: MIMPE203		Advanced Casting Process	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Casting processes: Classification, Metal mould casting processes, principles of melting practice-fluxing- degasification and inoculation- types of furnaces- Crucibles, Cupola, Oil fired furnaces – Electric arc and induction furnaces –Melting practice of cast iron, SG iron, steel, aluminium and copper alloys. Advanced casting processes, investment casting, Rheocasting, continuous casting process, centrifugal casting process. Evaporative pattern casting-ceramic mould casting –electromagnetic moulding-squeeze casting –shell moulding		
Module -II		[08]	
	Principle of Stir casting, steps in stir casting process, Factors affecting in stir casting process: stirring speed stirring time and temperature, preheat temperature of the mold, particle distribution, wettability between reinforcement and liquid metal and porosity, Advantages and application, composite preparation, analysis of composite, Squeeze casting, process, advantages Slip casting: principle, applications, advantages and limitations. Gel casting: principle, applications, advantages and limitations.		
Module -III		[08]	
	solidification, heat transfer during solidification, heat flow in solidification, ferrous and non-ferrous foundry practice, steel casting, aluminum and its alloys, magnesium and its alloys.		
Module -IV		[08]	
	Solidification of Metals and Alloys: Nucleation, Growth, Role of alloy constitution, Principles of Gating and Riser system: Types of Gates and Risers, gating ratio, design of rising system, criteria for riser design, method for improving riser efficiency, Chvorinov rule, concept of directionality in solidification Significance and practical control of cast structure, Caines method, modulus method.		
Module -V		[08]	
	Special casting Methods: Investment casting, die casting, Centrifugal casting, Full mould casting, Vacuum sealed casting. Casting Defects: A detailed analysis of casting defects Their causes and prescription of remedial measures		
TEXT BOOK(S):			
1.	P. R. Beeley, Foundry Technology, Newnes -Butterworths, 2001		
2.	P. D. Webster, Fundamentals of Foundry Technology, Portwillis press, Red hill, 1980.		
REFERENCE BOOK(S):			
1.	Advanced Casting Technology by J. Easwaran		
2.	Advanced Casting technologies by T. R. Vijayaram		
COURSE OUTCOMES: <i>After successful completion of this course, students will be able to:</i>			
CO1	Apply the knowledge to demonstrate advanced casting processes with appropriate furnace selection.		
CO2	Analyze the thermal, metallurgical aspects during casting solidification.		
CO3	Design the gating system and riser to achieve sound casting.		
CO4	Develop understanding of the dependent and independent variables which control materials		

	casting in a production process.
CO5	Recognize casting induced defects using diverse techniques and diverse foundry practice of ferrous and non-ferrous alloys.

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	2	3	2	2	2

Subject Code: MIMPE204		Advanced Composite Material	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Introduction to composite materials, classification of composite materials, Different types of matrix and reinforcement materials, Effects of fiber, matrix and interface on the properties of composite materials, synthesis of glass, carbon, aramid, and boron fiber.		
Module -II		[08]	
	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.		
Module -III		[08]	
	Synthesis of metal matrix composites (MMCs): Aluminium, Copper, Titanium and Magnesium based composite materials by solid state processing and in situ processing.		
Module -IV		[08]	
	Synthesis methods for various Ceramic matrix Composites (CMCs): Cold pressing and sintering, hot pressing. Processing, properties and applications of alumina matrix composites - SiC whisker reinforced, zirconia toughened alumina; Glass-ceramic matrix composites; Carbon-carbon composites. Toughening mechanisms in composite materials: crack bowing, crack deflection, de-bonding, pull-out, micro-crack toughening, transformation-toughening.		
Module -V		[08]	
	Polymer matrix composites (FRPs): Processing of thermoplastic and thermoset matrix composites. Self- propagating high temperature synthesis, Nano composites, Bio-composites, Self-healing and Self-reinforced composites, Polymer clay nanocomposites		
TEXT BOOK(S):			
1.	Analysis and performance of composite materials by B.D. Agarwal, L.J. Broutman and K. Chandrasekhar, Wiely		
2.	K.K.Chawla, Composite Materials – Science & Engineering, Springer-Verlag, New York		
REFERENCE BOOK(S):			
1.	Mechanics of composite Materials by R.M.Jones, Mc Graw Hill Book Co.		
2.	Fibre-Reinforced composites-Materials, Manufacturing and Design. P.K.Mallick Marcel Dekken, Inc. New York & Basel		
COURSE OUTCOMES: <i>After successful completion of this course, students will be able to:</i>			
CO1	Express classification of composite materials, merits and demerits.		
CO2	Demonstrate the processing of FRP composites.		
CO3	Evaluate the concept of different toughening mechanism and fabrication methods for CMCs.		
CO4	Analyze the advantages and limitations between nano-, bio-, and hybrid composite.		
CO5	Develop an idea about the characteristics and properties of self-healing and polymer clay nano composite.		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	2	2	3	3	2

Subject Code: MIMPE205		Thermomechanical Engineering	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	General introduction, Microstructure and Properties: Solidification, Interfaces, Properties: Physical Properties, Chemical Properties, Mechanical Properties, Electrical Properties, Magnetic Properties, Thermal Properties, Plasticity: Introduction, Fundamentals, Flow Stresses and Strains, Generalized Stresses and Strains, Yield Criteria, Stress–Strain Relations, Plastic Anisotropy, Fracture, Failure Mechanisms		
Module -II		[08]	
	Work hardening Mechanisms and theories: Introduction, Basic Microscopic Mechanisms, Low Temperature, Influence of Alloying Elements, Microscopic Hardening Laws, Hot Deformation, Flow Stresses, Hot Deformation Microstructures, Softening mechanisms: Introduction, Recovery, Recovery Mechanisms, Recovery Kinetics, Structural Changes During Recovery, Extended Recovery.		
Module -III		[08]	
	Continuous Recrystallization, Sources of Recrystallized Grains, Recrystallization Mechanisms, Recrystallization Kinetics, Role of Second Phase, Dynamic Recrystallization, Grain Coarsening, Theories of Grain Coarsening, Factors Affecting Grain Growth, Alternative deformation mechanisms: Introduction, Deformation Mechanism Maps.		
Module -IV		[08]	
	Creep, The Creep Curve, Creep Mechanisms, Influence of the Microstructure, Grain Boundary Sliding, GBS and Superplasticity, Conditions for Superplasticity, Twinning, Introduction, Twinning Mechanism, Influence of Some Parameters on Twinning, Twinning and Deformation, Phase transformations during thermo-mechanical processing.		
Module -V		[08]	
	Textural developments during thermo-mechanical processing, Residual stress modeling of texture and microstructural evolution, Forming Techniques, Defects in TMP, Physical Simulation of Properties, Case studies: Thermo mechanical processing of steel, aluminum, magnesium, titanium and other advanced alloy systems, recent trends in thermo mechanical processing, new Technologies.		
TEXT BOOK(S):			
1.	Recrystallization and related phenomena - F.J. Humpherys and M. Hatherly		
2.	Thermo-mechanical Processing of Metallic Materials - Bert Verlinden, Julian Driver, Indradev Samajdar, Roger D. Doherty		
REFERENCE BOOK(S):			
1.	Physical Metallurgy Principles by Robert E. Reed-Hill		
2.	Thermo-Mechanical Processing of Metallic Materials by Bert verlinden and Julian H. Driver		
COURSE OUTCOMESS: <i>After successful completion of this course, students will be able to:</i>			
CO1	Develop understanding of different testing techniques and their relationships for homogenous, isotropic materials.		
CO2	Evaluate the necking phenomena and distribution of stresses occurs in metals and alloys.		

CO3	Apply effect of gauge length, effect of strain rate and temperature on flow properties, machine stiffness in tensile testing system in tensile testing of a materials.
CO4	Implement the knowledge of fracture mechanics, fracture toughness and plane-strain toughness for design and application aspect.
CO5	Apply the knowledge of fatigue test, creep test and non-destructive testing.

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	1	3	2	3

Subject Code: MIMPE206		Ceramic materials	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Review of crystallography and crystal structure, Review of structure of atoms, molecules and bonding in ceramics, Discussion on structure of ceramics, Effects of structure on physical properties, Ceramic Phase diagrams.		
Module -II		[08]	
	Discussion on defects in ceramics, Introduction to glass, Discussion on processing of ceramic, Introduction to sintering and grain growth, Introduction to mechanical properties of ceramics.		
Module -III		[08]	
	Introduction to electrical properties of ceramics, Introduction to bio-ceramics, Introduction to magnetic ceramics, Topics covered, Introduction to crystal structure and crystallography, Fundamentals of structure of atoms, Structure of ceramics and its influence on properties.		
Module -IV		[08]	
	Binary and ternary phase diagrams, Point defects in ceramics, Glass and glass-ceramic composites, Ceramics processing and sintering.		
Module -V		[ 08]	
	Mechanical properties of ceramics, Electrical properties of ceramics, Bio-ceramics, Ceramic magnets.		
TEXT BOOK(S):			
1.	Carter, C.B. and Norton, M.G. Ceramic Materials Science and Engineering, Springer, 2007.		
2.	Ceramic Materials: Processes, Properties and Applications by P Boch, J C Niepce		
REFERENCE BOOK(S):			
1.	Ceramic and Glass Materials by Shackelford, James, Doremus, Robert H.		
2.	Ceramic Processing and Sintering by Mohamed N. Rahaman		
COURSE OUTCOMESS: <i>After successful completion of this course, students will be able to:</i>			
CO1	Write various traditional and advanced ceramic products and recognize industries those manufacture them		
CO2	Recognize the ceramic products in day to day as well as industrial application.		
CO3	Express preparatory methods for the various ceramic products.		
CO4	Draw binary and ternary phase diagrams.		
CO5	Write about processing of bulk ceramics and applications of ceramic materials in structural, biological and electrical components.		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	2	2	2	3	2	2

Subject Code: Common		Minor Project/Research Seminar	
Pre-Requisite:		Co-requisite:	
<p>For the Minor Project/Research Seminar, the students are encouraged either to carry out minor projects (simulation or experimental) or collect the information on a specialized current topic pertaining to the domain of industrial metallurgy and prepare a technical report, showing his understanding of the project work/topic of interest, and submit it to the department. It shall be evaluated by the departmental committee consisting of head of the department, seminar supervisor and senior faculty members. The assessment is based on the quality of presentation, report and viva voce. Further, the allocation of supervisors for the minor and major project work will be done based on the exhibition of student's work in the seminar.</p>			
COURSE OUTCOMES: After successful completion of this course, students will be able to:			
CO1	Review the literature both at national and international levels and define a specific problem through gap analysis.		
CO2	Identify and focus on an emerging area of research in the field of metallurgical and materials engineering, specifically industrial metallurgy.		
CO3	Perform research analysis to interpret the simulation/experimental data generated.		
CO4	Draw conclusions and also suggest scope for further work.		
CO5	Demonstrate satisfactorily the scientific principles and engineering ideas behind the research project undertaken and communicate effectively through oral or written or pictorial means.		

#### Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

#### Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	3	3	3	3

<b>Subject Code: MMMIM203</b>		<b>Industrial Metallurgy Lab-III(Powder Metallurgy and composite Laboratory)</b>	
<b>Pre-requisite:</b>	None	<b>Co-requisite:</b>	None
<b>LIST OF EXPERIMENTS</b>			
1.	To Determination the particle size and size distribution of different metal powders by using particle size analyzer Study of electron microscope (SEM &TEM)		
2.	To determine the apparent, tap density and flow rate of Al, Cu and Fe metal		
3.	Demonstrate the effect of compaction pressure, particle geometry, binders and lubricant on the green strength		
4.	Study the effect of sintering temperature and time on an alloy and a composite and evaluate the microstructure		
5.	Effect of milling speed and milling time on the mechanical properties of an alloy and a composite		
6.	Fabrication glass fiber reinforced polymer matrix composite		
7.	Synthesis of natural fiber reinforced polymer matrix composite		
8.	Fabrication of metal matrix composite by hand lay-up method		
<b>COURSE OUTCOMESS:</b> <i>At the end of this course, students will demonstrate the ability to:</i>			
CO1	Develop basic knowledge of measuring different metallic and ceramic powder particle		
CO2	Measure the density and flow rate metallic and ceramic powder particles.		
CO3	Develop the knowledge of different compaction techniques.		
CO4	Analyze the different types of sintering methods		
CO5	Develop an idea about the properties and processing of PMCs, MMCs, and PMCs.		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	2	3	2	3

Subject Code: MMMIM204		Industrial Metallurgy Lab-IV(Material Characterization Laboratory)	
<b>Pre-requisite:</b>	None	<b>Co-requisite:</b>	None
<b>LIST OF EXPERIMENTS</b>			
1.	Study of electron microscope (SEM &TEM)		
2.	Micro structural analysis of a given (Ferrous & Nonferrous) sample using Optical and scanning electron Microscope		
3.	Determination of interlamellar spacing of pearlite using SEM		
4.	Study of precipitation hardening of Al-Cu alloy using SEM		
5.	Compositional Analysis of an unknown sample using EDX		
6.	Sample preparation technique for powder sample to be studied under SEM		
7.	Fractography using scanning electron microscope		
8.	Indexing of XRD Pattern of a given sample		
9.	Determination of lattice parameter of a given sample		
10.	Determination of crystallite size and lattice strain of a powdered sample using XRD		
<b>COURSE OUTCOMESS:</b> <i>At the end of this course, students will demonstrate the ability to:</i>			
CO1	Perform the structural analysis of a given sample.		
CO2	Select appropriate methods for particular problems and have a good understanding of the data obtained.		
CO3	Prepare the specimens for metallographic examination with best practice		
CO4	Operate the optical and Scanning electron microscope and understand, interpret, analyze the microstructure of materials		
CO5	Comprehend the behaviour and use of X-ray in material characterization		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “--“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	2	1	3	3	2

Subject Code: MIMPE301		Physics of Metal	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Introduction and Approach, Properties of materials and some important relationships, Free electron theory of metals, Drude model Electronic Conductivity, Drude model Thermal Conductivity – Ratio, The Wiedemann Franz Law.		
Module -II		[08]	
	Statistical Mechanics, Maxwell-Boltzmann statistics, history of quantum mechanics: Drude, Sommer field model, Fermi-Dirac Statistics; Confinement and quantization, calculating density of available states for electrons.		
Module -III		[08]	
	Fermi Energy, Fermi Surface, Fermi Temperature; Reciprocal space, Wigner Seitz cells Brillouin zones, Calculating allowed and forbidden energy levels, Description of tight binding approximation, impact of inter atomic spacing on band gaps.		
Module -IV		[08]	
	Comparison of free electron approximation and tight binding approximation, Effect of pressure on band gaps, Direct Band gap, indirect band gap semiconductors, Magnetic properties, Electron compounds/Hume Rothery phases.		
Module -V		[ 08]	
	Optoelectronic materials, Optoelectronic properties, superconductivity, Meissner effect, Bose-Einstein Statistics, BCS theory, High temperature superconductors, Phonons, Superconductivity, Bose-Einstein Statistics, Physics of nano scale materials.		
TEXT BOOK(S):			
1.	Structure and Properties of Materials (Vol.iv) - Electronic Properties by John Wulf, R.M. Rose and L.A. Shepard - (Wiley Eastern, 1964).		
2.	Introduction to the Modern Theory of Metals by Alan Cottrell - (Ashgate Publishing Company, 1988).		
REFERENCE BOOK(S):			
1.	Atomic Theory for students of Metallurgy by William Hume-Rothery and B.R. Coles - (Inst. Of Materials Ashgate Publishing Company, Sept. - 1988).		
2.	Principles of Electrical Engineering Materials by S.O. Kasap - (McGraw - Hill, 1977).		
COURSE OUTCOMESS: <i>After successful completion of this course, students will be able to:</i>			
CO1	Express the mechanical, electrical, thermal, magnetic and optical properties of materials.		
CO2	Analyze the importance of material properties for a wide variety of engineering situations.		
CO3	Evaluate and select suitable materials for different practical applications.		
CO4	Develop typical values of the properties of common practical materials.		
CO5	Analyze the micro-physics and chemistry responsible for material properties, and analyze how they can be modified.		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	2	3	3	2

Subject Code: MIMPE302		Environmental Degradation and Corrosion	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Electrochemistry of corrosion: Corrosion: Introduction – Definitions and Types(Uniform , Galvanic ,Pitting, Crevice), Electrochemical Cells –Definitions and Principles, Potential Measurements - Galvanic Cells, Concentration Cells.		
Module -II		[08]	
	EMF and Galvanic Series - Bimetallic Couples, thermodynamic aspects of Corrosion, relation between free energy and equilibrium constant, Derive Nernst equation, standard reduction potential series of Pure Metal,Limitation of Reduction Potential, Concentration cell and Spontaneity of Corrosion Process.		
Module -III		[08]	
	Eh-pH Diagrams – Fundamental Aspects, Construction of Eh – pH Diagrams (Fe- H <sub>2</sub> O – O <sub>2</sub> ) Diagram.Electrode kinetics and polarization phenomena: Electrode-Solution Interface – Definition and Types of Polarization.		
Module -IV		[08]	
	Exchange Current Density – Polarization Relationships, Polarization Techniques – Corrosion Rate Determination, Mixed Potentials – Concepts and Basics, Mixed Potential Theory – Bimetallic Couples, Mixed Potential Theory – Activation and Diffusion Controlled Processes.		
Module -V		[ 08]	
	Method of corrosion control: Prevention Strategies – Design and Coatings, Prevention Strategies – Inhibitors and Surface Engineering, Cathodic Protection – Principles and Classification, Cathodic Protection –Influencing Factors and Monitoring, Design Aspects of Cathodic Protection, Passivity – Definitions and Influencing Parameters, Application of Mixed Potential Theory, Design of Corrosion Resistant Alloys.		
TEXT BOOK(S):			
1.	U.K.Chatterjee,S.K BoseandS.KRoy:EnvironmentalDegradationofMetals,MarcelDekker, 2001		
2.	M.G.Fontana:CorrosionEngineering,3 <sup>rd</sup> edition,McGraw Hill International,1987		
REFERENCE BOOK(S):			
1.	Glasstone S., An Introduction to Electrochemistry, Van Nostrand.		
2.	Narain S. and Saran R., An Introduction to Electrometallurgy, Standard Publishers.		
COURSE OUTCOMESS:After successful completion of this course, students will be able to:			
CO1	Apply fundamental knowledge and concepts in corrosion and List various atmospheres responsible for corrosion.		
CO2	Classify and express Characteristic features, causes and remedial measures of different forms of corrosion		
CO3	Evaluate working of different metallic coating works at different temperature.		
CO4	Calculate corrosion rate using Tafel extrapolation and linear polarization techniques and select, test materials and apply corrosion prevention methods		

CO5	Compare high temperature metal-gas reactions and corrosion of metals at high temperature in atmospheres such as sulphur dioxide, chlorine etc
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Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	2	2	3	3	2

Subject Code: MIMPE303		Surface Engineering and Coating Technology	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Introduction to surface-thermodynamics of surface, Surface dependent properties-physical, Chemical and Mechanical; Surface dependent degradation and their characteristics, analysis of surface-initiated degradation; Approaches and classifications of surface engineering techniques.		
Module -II		[08]	
	Surface modifications techniques-conventional Surface Modification Methods Applicable to Steel, Cast Iron, and Non-ferrous Metals/Alloys- Shot peening, sand blasting, Flame, induction hardening, Solid State Diffusion Assisted Surface Modifications; Emerging surface modification techniques- chemical route (electroless deposition, sol-gel coating), electro-chemical routes (electro deposition, electro-phoretic deposition).		
Module -III		[08]	
	Chemical conversion coatings - hot dipping, Thermal spraying; Surface Painting- Basic paint technology, polymeric binders, pigments and extenders, additives, essential concepts of paint formulation and paint properties, paint preparation (pigment dispersion), surface preparation and paint application techniques applied for film preparation and their properties.		
Module -IV		[08]	
	This Film Technologies-Development of Metallic and Ceramic Thin film by physical routes (thermal evaporation, sputtering and ion plating).		
Module -V		[08]	
	This Film Technologies-Development of Metallic and Ceramic Thin film by physical routes by chemical route (chemical vapor deposition); Directed energy beam assisted surface engineering techniques (ion, electron beam and laser assisted surface engineering techniques), Economics and designing of surface engineering processes.		
TEXT BOOK(S):			
1.	Surface Engineering for Wear Resistance by K. G. Budinski, Prentice Hall, New Jersey 1988.		
2.	Surface Engineering for Corrosion and Wear Resistance by J. R. Davis, ASM International, Materials Park, Ohio, 2001.		
REFERENCE BOOK(S): After successful completion of this course, students will be able to:			
1.	Surface treatments for protection, Series 3, No. 10, The institute of metallurgist series.		
2.	Rabinowicz, E., Friction and Wear of Materials, Wiley		
COURSE OUTCOMES:			
CO1	Develop a basic knowledge about surface engineering.		
CO2	Analyze the concept of different conventional surface engineering methods		
CO3	Demonstrate a comprehensive overview of the latest developments in surface engineering and coating technologies		
CO4	Express the advanced coating technologies with an emphasis on thermal, chemical and physical vapor deposition techniques		

CO5	Implement the advanced surface modifications through electron, ions and laser beams
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Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	3	2	3	1

Subject Code: MIMOE301		Material Recycling and Waste management	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Introduction: Introduction to recycling of materials, statistics on materials recycling, recycling chain, principles of recycling, Economical, technological and environmental aspects of materials recycling.		
Module -II		[08]	
	Recycling of Materials: Recycling of metals and rare-earth metals, polymers, composites, electronic wastes, nuclear materials and nuclear wastes, recycling of (lead-acid, lithium-ion) batteries, recovery from lean sources.		
Module -III		[08]	
	Materials wastes: Primary and secondary solid wastes in metallurgical and powder industry, Wastes from polymer and ceramic industries, Nuclear waste.		
Module -IV		[08]	
	Waste Management: Economic uses of solid waste such of B.F. slag and fly ash & wastes from metallurgical and materials industry Energy saving: Alternative routes of processing of materials for energy saving, Role of optimal selection of materials processing route, Conservation through protection of materials against decay, Waste heat recovery methods.		
Module -V		[08]	
	Environmental Protection: General concepts of environment, toxicology of materials, Stack gases of Electric Arc Furnaces and industrial production processes.		
TEXT BOOK(S):			
1	Ernst Worrell, Markus Reuter (Eds): Handbook of Recycling, Elsevier, 2014.		
2	Donald L. Stewart, James C. Delay, Robert L. Stephens: Recycling of Metals and Engineered Materials (Proceedings of fourth international symposium), TMS Publications, 2000.		
REFERENCE BOOK(S):			
1	Sustainable Solid Waste Management edited by Jonathan W. C. Wong; Rao Y. Surampalli; Tian C. Zhang; Rajeshwar D. Tyagi; and Ammaiyappan Selvam		
2	Waste Management Practices By John Pichtel		
COURSE OUTCOMES: After successful completion of this course, students will be able to:			
CO 1	Describe methods of recycling of engineering materials		
CO 2	Comprehend recycling of materials waste		
CO 3	Identify and express types and sources of materials waste		
CO 4	Analyze the economics, social and environmental impact of materials waste and its recycling		
CO 5	Apply the different technique to convert waste to wealth		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	2	2	3	2	3	2

Subject Code: MIMOE302		Advanced Material	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Organic electronics, Melanin, Organic semiconductor, Organic LED, Nanostructures, Nanomaterials, Nanocomposites, hard materials.		
Module -II		[08]	
	High entropy alloys, bulk metallic glasses, multi-component alloys and their application in metallurgical industries, Smart Materials: Piezoelectric materials, Shape memory alloys and shape memory polymers.		
Module -III		[08]	
	High Performance Alloys: Nickel and Co- based super alloys, Ti alloys, Al-Li alloys, metallic foam.		
Module -IV		[08]	
	Functional and Engineering Ceramics: diverse applications as cutting tools, mobile phone microwave devices, polycrystalline diamond and fuel cells.		
Module -V		[ 08]	
	Hybrid Materials: Design, Synthesis and Properties of hybrid materials created by blending disparate materials such as plastics with metals, functionally graded materials.		
TEXT BOOK(S):			
1.	Mark J. Hampden-Smith Wiley-VCH, Chemistry of Advanced Materials: An Overview Leonard V.Interrante, 1 <sup>st</sup> edition(1997)ISBN-10: 0471185906ISBN-13: 978-0471185901.		
2.	R E Smallman, A. H. W., Butterworth-Heinemann, Physical Metallurgy and Advanced Materials,SeventhEdition, 2007,ISBN: 0750669063		
REFERENCE BOOK(S):			
1.	Ray A.K. (ed), Advanced Materials, Allied Publishers.		
2.	Rama Rao P. (ed), Advances in Materials and Their Applications, Wiley Eastern Ltd. 4. Bhushan B., Nano Technology (ed), Springer		
COURSE OUTCOMESS: <i>After successful completion of this course, students will be able to:</i>			
CO1	Express the recent world of miniaturization.		
CO2	Develop the understanding of recent nanotechnology applications and its advantages.		
CO3	Organize diverse synthesis process which may lead to develop new nanostructures with improved properties.		
CO4	Evaluate different alloy system for diverse application.		
CO5	Plan processing of advanced materials.		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	1	3	2	1

Subject Code: MIMOE303		X-ray and Electron Microscopy	
Pre-Requisite:		Co-requisite:	
Module -I		[08]	
	Introduction to crystallography, Symmetry - point group and space group, X - ray diffraction and analysis: Production and properties of X - rays, X - ray diffraction, Structure factor and intensity calculations. Continuous and characteristics spectrum, absorption. Filter and detectors, Bragg's law, scattering by atom, electron, unit cell, and structure factor calculation.		
Module -II		[08]	
	Diffraction Methods: Laue's method, rotating crystal, Debye Scherer – Specimen preparation, film loading, powder method, Determination of crystal structure, determination of precision lattice parameter, sources of error in measurements.		
Module -III		[08]	
	Determination of particle size, grain size, residual stresses, determination of phase diagrams, order - disorder transformation, texture, importance of texture, measurement of texture, pole figures (stereographic projections), orientation distribution function, sample symmetry.		
Module -IV		[08]	
	Electron optical methods – I: Scanning electron microscopy and X-ray microanalysis including electron probe microanalysis, electron optics, electron beam specimen interaction, image formation in the SEM. X- ray spectral measurements: WDS and EDS, quantitative X-ray analysis.		
Module -V		[ 08]	
	Electron optical methods – II: Analytical transmission electron microscopy: Electron diffraction, reciprocal lattice, analysis of SAD patterns; different electron diffraction techniques, atomic resolution microscopy, analytical devices with TEM, field ion microscopy, and scanning tunneling microscopy, advanced techniques.		
TEXT BOOK(S):			
1.	Elements of X-Ray Diffraction by B. D. Cullity, Adison-Wesley.		
2.	Materials Characterization, Metals Handbook, Vol. 10, ASM		
REFERENCE BOOK(S):			
1.	X-Ray Diffraction Crystallography by Waseda, Yoshio, Matsubara, Eiichiro, Shinoda, Kozo		
2.	Basics of X-Ray Diffraction and its Applications by K. Ramakanth Hebbar		
COURSE OUTCOMESS: <i>After successful completion of this course, students will be able to:</i>			
CO1	Perform analysis and measurements using x-ray techniques.		
CO2	Develop the understanding of the operation of light and electron interaction with materials to get an image in different scales.		
CO3	Organize electron beam/materials interaction to form an image, x-ray microanalysis.		

CO4	Acquire experimental data individually or in a team from x-ray diffraction, optical and electron microscopy and prepare reports.
CO5	Perform statistical analysis of the experimental data acquired.

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	3	3	3	1

Subject Code: Minor Project		Dissertation (Phase-I)	
Pre-Requisite:		Co-requisite:	
<p>Students are encouraged to carry out multidisciplinary projects from third semester onwards and in consultation with the allocated supervisor. The supervisors will help the students to identify the Project based on the area of interest to apply their engineering knowledge so as to solve practical problems and meet the sustainability, societal and environmental needs. Periodical project progress seminars/reviews will be conducted and students are asked to present project scopes, novelty, proposed technical achievement, methodology and expected outcome of the proposed work. The project work carried out at this semester is expected to be extended to the succeeding semester. At the end of the semester, projects are evaluated by the external examiner.</p>			
<p><b>COURSE OUTCOMES:</b> <i>After successful completion of this course, students will be able to:</i></p>			
CO1	Review the literature both at national and international levels and define a specific problem through gap analysis.		
CO2	Identify and focus on an emerging area of research in the field of metallurgical and materials engineering, specifically industrial metallurgy.		
CO3	Perform research analysis to interpret the simulation/experimental data generated.		
CO4	Draw conclusions and also suggest scope for further work.		
CO5	Demonstrate satisfactorily the scientific principles and engineering ideas behind the research project undertaken and communicate effectively through oral or written or pictorial means.		

#### Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

#### Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	3	3	3	3

Subject Code: Major Project		Dissertation (Phase-II)	
Pre-Requisite:		Co-requisite:	
<p>The Project Work is the significant part of the PG curriculum that provides the students the opportunity to synthesize and apply the knowledge and analytical skills learned during their post-graduation. Every student is assigned with a project works to capture their interest and to improve their ability to solve real life problems through socially relevant project works. It enables the student to think innovatively on the development of components, products, processes or technologies in metallurgical and materials engineering domain. Students are encouraged to carry out multidisciplinary projects to apply their engineering knowledge so as to solve practical problems and meet the sustainability, societal and environmental needs. Periodical project presentation is conducted and students are asked to present project scopes, novelty, proposed technical achievement, methodology and expected outcome of the proposed work. At the end of the semester, projects are evaluated by the external examiner.</p>			
<p><b>COURSE OUTCOMESS:</b><i>After successful completion of this course, students will be able to:</i></p>			
CO1	Review the literature both at national and international levels and define a specific problem through gap analysis.		
CO2	Identify and focus on an emerging area of research in the field of metallurgical and materials engineering, specifically industrial metallurgy.		
CO3	Perform research analysis to interpret the simulation/experimental data generated.		
CO4	Draw conclusions and also suggest scope for further work.		
CO5	Communicate effectively through oral or written or pictorial means.		

Course Articulation Matrix

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

1: Slight (Low); 2: Moderate (Medium); 3: Substantial (High); “---“: No Correlation

Program Articulation Matrix row for this Course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	3	3	3	3	3

