COEP Technological University Pune

(A Unitary Public University of Govt. of Maharashtra)

School of Engineering and Technology

Curriculum Structure

T. Y. B.Tech.

Metallurgy and Materials Technology

Department of Metallurgy and Materials Engineering

(Effective from: A.Y. 2025-26)

List Of Abbreviations

Abbreviation	Title
AEC	Ability Enhancement Course
BS	Basic Science Course
ESC	Engineering Science Course
PCC	Programme Core Course
PEC	Programme Elective Course
OE/SE	Open/School Elective other than particular program
MDM	Multidisciplinary Minor
VSEC	Vocational and Skill Enhancement Course
HSMC	Humanities Social Science and Management
IKS	Indian Knowledge System
VEC	Value Education Course
RM	Research Methodology
INTR	Internship
PBL	Project
CEA	Community Engagement Activity/Field Project
CCA	Co-curricular & Extracurricular Activities

T. Y. B. Tech. Metallurgy and Materials Technology
Semester - V

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
01	PCC	<tbd>	Heat Treatment Technology	3	0	2	1	4	30	20	50	50	50
02	PCC	<tbd>	Materials Characterization	3	0	2	1	4	30	20	50	50	50
03	PCC	<tbd>	Structural Metallurgy	2	0	0	1	2	30	20	50	-	
04	PCC	<tbd>	Department Elective-I	3	1	0	1	4	30	20	50	-	
			1. Powder Metallurgy										
			2. Surface Processing of Materials										
			3. Energy Materials										
			4. Semiconductor Devices										
05	OE	<tbd>	Materials and Processes for e-Mobility	2	0	0	1	2	30	20	50	-	-
06	MDM-II	<tbd>	Agro Waste Management	4	0	0	1	4	30	20	50		
07	INTR	<tbd>	Internship	0	0	6	0	1	-	-	-	CIE: 100	
08	AEC-II	<tbd>	Project stage I	0	0	4	0	2	-	-	-	50	50
			Total	**17**	**01**	**14**	**06**	**23**					

Legends: L-Lecture, T-Tutorial, P-Practical, S-Self Study, Cr-Credits
ISE-In-Semester-Evaluation, ESE-End-Semester-Evaluation,
MSE-Mid-Semester Evaluation, TA-Teachers' Assessment,
CIE-Continuous-Internal-Evaluation

T. Y. B. Tech. Metallurgy and Materials Technology
Semester - VI

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
01	PCC	<tbd>	Transport Phenomena	2	1	0	1	3	30	20	50	-	
02	PCC	<tbd>	Iron and Steel Making	3	0	0	1	3	30	20	50	-	-
03	PCC	<tbd>	Foundry Technology	3	0	2	1	4	30	20	50	50	50
04	PCC	<tbd>	Materials Software Tool Lab	0	0	2	1	1	-	-	-	CIE:100	
05	PCC	<tbd>	Department Elective-II	3	1	0	1	4	30	20	50	-	-
			1. Material Joining										
			2. Non-Destructive Testing & Chemical Characterization										
			3. Advanced Composite Materials										
			4. EV Materials										
06	MDM-II	<tbd>	Plastic Waste Management	4	0	0	1	4	30	20	50	--	--
07	VSEC	<tbd>	Project Stage II	0	0	4	0	2	30	20	50	50	50
			Total	**15**	**02**	**08**	**06**	**21**					

Legends: L-Lecture, T-Tutorial, P-Practical, S-Self Study, Cr-Credits
ISE-In-Semester-Evaluation, ESE-End-Semester-Evaluation,
MSE-Mid-Semester Evaluation, TA-Teachers' Assessment,
CIE-Continuous-Internal-Evaluation

T.Y. B.Tech. Metallurgy and Material Technology

Course: HEAT TREATMENT TECHNOLOGY

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of course students will be able to:

1. Understand the basic principles of various heat treatments.
2. Analyse the effect of heat treatment processes on the micro-structure and properties of materials
3. Design of various heat treatment cycles using phase diagrams, TTT, CCT diagrams
4. Design of thermo-mechanical treatment for micro-alloy steel, dual phase steel, tool steel Maraging steel and stainless steel
5. Compare various surface heat treatments given to steels
6. Analyse effect of furnace atmospheres on heat treatment processes and reasons behind defects after heat treatments

Syllabus:

Unit	Contents	Lecture
01.	**Heat treatment of plain carbon steels**: Annealing, Isothermal and subcritical Annealing types, Normalizing, Hardening Heat Treatment, Quenching medias, Quenching Mechanism, Quenching Fixtures, Tempering and subzero treatment. Dimensional changes during hardening and tempering. Austempering, Martempering, Ausforming, Isoforming, patenting. **Self-study:** Iron -Iron Carbide Diagram, TTT and CCT diagram, Transformation product of austenite	**06**
02.	**Hardenability:** Mass effect, Grossman method, Critical and ideal critical diameter, Jominy End Quench method, Use and Significance of Hardenability data, Effect of grain size and composition, Heat Treatment Defects such as Distortion, Residual stresses, quench cracks. **Effect of alloying element on heat treatment Processes:** Role of alloying element in steel, Classification of alloying elements and their effects on: Iron–Iron carbide phase diagram, TTT Diagram and CCT Diagram. **Self-study:** Case studies of design changes for hardening	**06**
03.	**Stainless steel and their heat treatments:** Fe-Cr, Fe-Ni Phase Diagram, Schaeffler Diagram and its	**06**

	modifications, Classification of Stainless Steels, sensitization, Heat treatment of stainless steels, Precipitation Hardening Stainless Steels, Maraging Steels. **Self-study:** Applications of stainless steels	
04.	**Heat treatment of tool steels:** Classification of Tool Steels: Cold work, Hot Work Tool Steels, High Speed Steels and Stellites; Heat treatment of high-speed steel and super high speed steel, Heat treatments of Die and Tool steels, Secondary hardness and Red Hardness. **Self-study:** Applications of tool steel	
05.	**Thermomechanical Processing of Steels:** Basics of thermomechanical processing, Dynamic recrystallization and its types, Controlled thermomechanical processing of low alloy steels, DP steels, TRIP steels and TRIP assisted Steels, QP steel TWIP steels. **Self-study:** Hot and cold working, Evolution of dislocation density during hot and cold working, Industrial steel subjected to thermomechanical treatments.	**06**
06.	**Surface hardening:** Selection of steels for surface hardening treatments, Carburizing, Carburizing atmosphere and post Heat treatments, Case depth measurement, Nitriding, Carbonitriding, Tufftriding, Nitrocarburizing, Plasma Nitriding; Induction Hardening, Flame Hardening, Laser Hardening, **Self-study:** Case depth measurement ASTM standard	**06**

Suggested learning resources:

Textbooks:

1. Heat Treatment of Metals, Vijendra Singh, 2007, Standard Publishers and Distributors, New Delhi
2. R.A. Higgins, Engineering Metallurgy, Part I, App. Physical Met, ELBS, 5th ed., 1983
3. H. K. D. H. Bhadeshia, Robert Honeycombe, Steels:Microstructure and Properties, Third edition, Publisher Elsevier Ltd., UK

Reference Books:

1. Steel and its Heat Treatment -K.E Thelning, Butterworth, London
2. Handbook of Heat Treatment of Steels – Prabhudev-Tata McGraw Hill. New Delhi, 1988
3. Heat Treatment of Ferrous Alloys, Brooks, Washington: Hemisphere Pub., 1979
4. ASM Metals Handbook – Heat treatment, Metals Park Ohio Pub.
5. ASM Metals Handbook – Steels, Metals Park Ohio Pub.

T.Y. B.Tech. Metallurgy and Material Technology

Course: HEAT TREATMENT TECHNOLOGY LABORATORY

Course Code		**Scheme of Evaluation**	ISE and ESE
Teaching Plan	0-0-2-0 = 2	**ISE**	50
Credits	1	**ESE**	50

Course Outcome

At the end of course students will be able to

1. Interpretation of microstructures and corelate structure property relationship.
2. Design of heat treatment cycles using TTT/CCT diagram.
3. Analyzing and comparing various heat treatment cycles.

Syllabus:

List of Experiments: (Any 08 from the given below)

1. Performing annealing and normalizing heat treatment of steel samples; observation of microstructures and hardness measurement.
2. Performing hardening and tempering heat treatment of steel samples; observation of microstructures and phase analysis using ImageJ or suitable software. Hardness ES.
3. Designing of Spheroidizing annealing cycle for eutectoid steel.
4. Hardenability determination by Jominy End Quench test as per ASTM standard.
5. Performing surface heat treatments like carburizing, nitriding on steels; estimating resultant case depth.
6. Study of isothermal heat treatment cycle using TTT/CCT diagram for various types of steels.
7. Performing hardening and multiple tempering of High-Speed Steel.
8. Determination of prior austenite grain size for a heat treatment.
9. Case Study of defects due to heat treatment and remedial design changes.
10. Comparison of austempering and QP heat treatments.
11. Study of heat treatment furnaces and furnace atmospheres.
12. Study of effect of alloy composition, heat treatment cycles, thermomechanical treatments on the microstructures and properties of ferrous alloys through various peer reviewed paper.

T.Y. B.Tech. Metallurgy and Material Technology

Course: MATERIALS CHARACTERISATION

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcomes:

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

1. Understand the basic principles of optical microscopy, electron microscopy, X-ray diffractometry and thermal analysis techniques.
2. Apply the knowledge of characterization techniques to inspect the characterization need pertaining to material's structure –processing –and property needs.
3. Analyze the outcome from various characterization techniques to interpret and present observations quantitatively and qualitatively.
4. Compare the various characterization techniques based on advantages, limitations, specifications and applications.
5. Design the characterization flowchart for a process or system based on material's structure-process-property relationship.

Syllabus:

Unit	Contents	Lectures
01.	**Optical microscopy** Fundamentals and instrumentation, Basic principles of image formation, General microscopy concepts: resolution, magnification, depth of field, depth of focus, sample preparation, types of optical microscopes, bright and dark field image formation, phase contrast, polarized light, differential interference contrast, fluorescence microscopy, image analyser, applications of optical microscopy, stereographic projection, standard projection. **Self-study:** Analysis of optical images.	**06**
02.	**General concepts of electron microscopy** Basic components of electron microscope (electron gun, electro-magnetic lenses), Aberrations (chromatic, spherical, astigmatism etc.) and their corrections, Electron-materials interaction (elastic vs. inelastic scattering, coherent vs. incoherent scattering, interaction volume). **Self-study:** Energy and wavelength spectra of electromagnetic radiations.	**03**

03.	**Transmission electron microscope** Image formation and contrast generation, Modes of TEM (bright field, dark field, HAADF, STEM), Electron diffraction in TEM, Concept of reciprocal lattice, Ewald sphere, diffraction from finite crystal, Diffraction pattern (Single crystal, Polycrystal & Selected area diffraction), Indexing of diffraction pattern, Application of electron diffraction (DF imaging, dislocation contrast, phase identification). **Self-study:** Young's double-slit experiment	**06**
04.	**Scanning electron microscope** Working principle, Signal generation: Inelastic scattering (Secondary vs. backscattered electron, Auger electrons, characteristic X-ray emission), Basic components of SEM, Detectors: SE (E-T detector), BSE, In-lense detector, Optics of SEM, Factors affecting resolution in SEM, SEM analysis of nonconducting samples, limitations of SEM, fractography, Applications of SEM. **Self-study:** Vacuum level in SEM chamber.	**06**
05.	**X-ray Diffraction** Production and properties of X-rays, Absorption and filters, diffraction of X-rays through crystals, Bragg's law and the factors affecting the intensity, Structure factor calculations, Laue method, Rotating Crystal method, Powder method, Indexing of diffraction pattern, Applications: Determination of type of lattice and lattice parameter, lattice strains, crystallite size, and residual stresses. **Self-study:** Planes, directions, Miller indices, Bragg's law derivation.	**09**
06.	**Other characterization techniques** Surface analysis by XPS, X-ray tomography, Scanning Probe Microscope (SPM), Scanning-Tunneling Microscope (STM), Atomic Force Microscope (AFM), and Auger Electron Spectroscopy (AES). **Self-study:** UV- Visible Spectrophotometer, FTIR Spectroscopy	**06**

Suggested learning resources:

Textbooks:

1. P.J. Goodhew, J. Humphreys, R. Beanland, Electron Microscopy and Analysis, 3rd Edition, Taylor and Francis, London.
2. Microstructure Characterization, Edited by E. Metcalfe, The Institute of Metals, USA.
3. B.D. Cullity, Elements of X-ray Diffraction (For X-rays), 3rd edition, Prentice-Hall, Upper Saddle River 2001.
4. Thomas & M.T. Goringe, Transmission Electron Microscopy of Materials, John Wiley, 1979.
5. L.E. Murr, Electron and Ion Microscopy and Microanalysis, Marcel Dekker, 1991.

Reference Books:

1. Padmakar R. Khangaonkar, An Introduction to Materials Characterization, Penram International Publishing (India) Pvt. Ltd.
2. Douglas B. Murphy and Michael W. Davidson, Fundamentals of Light Microscopy and Electronic Imaging, John Wiley & Sons, Inc.
3. Williams, David B., Carter, C. Barry, Transmission Electron Microscopy - A Textbook for Materials Science, Springer, 2009.
4. Goldstein, J., Newbury, D.E., Joy, D.C., Lyman, C.E., Echlin, P., Lifshin, E., Sawyer,
5. L., Michael, J.R., Scanning Electron Microscopy and X-Ray Microanalysis, Third Edition, Springer, 2003.

T.Y. B.Tech. Metallurgy and Material Technology

Course: MATERIALS CHARACTERIZATION LABORATORY

Course Code		**Scheme of Evaluation**	ISE AND ESE
Teaching Plan	0-0-2-0 = 1	**ISE**	50
Credits	1	**ESE**	50

Course Outcomes:

At the end of course students will be able to

1. Understand, use and compare various characterization equipment for conducting microstructure and grain size evaluation.
2. Apply the knowledge of crystal structure and X ray diffraction to determine the lattice constant, crystal structure and quantify the retained austenite and residual stresses in a sample.

List of Experiments (Any 8):

1. Determine the grain size of ferrous and nonferrous alloys using an optical microscope
2. Microhardness measurement of ferrous and nonferrous alloys
3. Demonstration of Bright field and Dark field image formation in transmission electron microscope (TEM)
4. Recording and indexing of electron diffraction pattern (TEM) from single crystal material
5. Analyzing surface morphology and fractography by Scanning Electron Microscopy
6. Recording and indexing of X-ray diffraction pattern (XRD) from cubic materials
7. X-ray diffraction analysis to determine the retained austenite content in the sample
8. X-ray analysis to determine the residual stresses in the deformed sample
9. Study of Different Types of Symmetry in Cubic Lattices
10. Monitoring the presence and concentration of dyes in wastewater using UV-visible Spectrophotometer
11. Analyze the composition and properties of materials using Fourier Transform Infrared (FTIR) spectroscopy

T.Y. B.Tech. Metallurgy and Material Technology

Course: STRUCTURAL METALLURGY

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	2-0-0-1 = 2	**MSE and TA**	30 and 20
Credits	2	**ESE**	50

Course Outcomes:

At the end of course, students will be able to

1. Understand fundamentals of dislocation theory, strengthening mechanisms, diffusion of solids nucleation and growth, solid state transformation, and creep resistant alloy
2. Apply knowledge of strengthening mechanism to improve strength of alloy
3. Analyzing effect of heterogeneous and homogeneous nucleation on overall transformation kinetics
4. Compare various solid state phase transformations
5. Establish structure-property correlations for various categories of materials.
6. Design different alloys like HSLA, creep resistant alloys etc. using understanding of fundamental concepts.

Syllabus:

Unit	Contents	Lectures
01.	**Dislocation Theory:** Elastic Properties of Dislocations, Strain Energy of Dislocations, Forces on and between Dislocations, Dislocations in FCC and other crystal structure, Climb and cross slip of Dislocations, Multiplication of Dislocations, Dislocation Pile Ups, Strengthening by Dislocations. **Self-study:** Methods of Observation of Dislocations, Yield Point Phenomenon	**04**
02.	**Strengthening Mechanisms:** Strengthening by Work Hardening, Grain Boundaries, dislocation model of small angle grain boundary, Strain Ageing, Solid Solution Strengthening, strengthening from fine particles, Texture Strengthening **Self-study:** Application of strengthening mechanism to design HSLA	**04**
03.	**Diffusion in Solids:** Types of diffusion, Fick's Laws of Diffusion, Solution of Fick's Laws and their Applications to various Metallurgical Processes- carburizing, semiconductors etc., Atomic theory of diffusion, diffusion couples, Kirkendall Effect, Diffusion paths along grain boundaries and free surfaces, Diffusion Kinetics. Nucleation and Growth: The nucleation, Homogeneous and Heterogeneous Nucleation, Strain Energy Effect, Growth kinetics: Interface-controlled growth and diffusion controlled growth, Overall transformation kinetics, recovery, recrystallization and grain growth. **Self-study:** Diffusion in ionic crystals	**08**
04.	**Kinetics and Solid State phase transformation:** Transformations in steels-Pearlitic and Bainitic transformation, Martensitic transformation-Bain distortion, nature and multiplicity of habit planes, stabilization, Dimensional changes, Iron–Nickel martensitic transformation, Order-Disorder transformations-dislocations	**08**

	and stacking fault in ordered structure, Massive transformation, Spinodal decomposition. Creep resistant alloys: Creep Mechanism, creep curve, Relation between dislocation density and stress, Creep Rupture Strength, Larsen Miller parameter, Super-plasticity. **Self-study:** Development of creep-resistant: shape memory alloys and alumina-forming ferrous alloys for high-temperature structural applications.	

Suggested learning resources:

Textbooks:

1. Derek Hull, D. J. Bacon, Introduction to Dislocations, Elsevier Science, 2011.
2. V. Raghvan –Solid State phase Transformation, PHI, 2010.
3. V. Raghvan - Material Science and Engineering,PHI,2004
4. Porter, Easterling Sherif -Phase transformation in Metals and Alloys-CRC Press, 2009
5. Robert Reed - Hill - Physical Metallurgy Principles, Thomson/Brooks/Cole,2005
6. R. E. Smallman and R. J. Bishop, "Modern Physical Metallurgy and Materials Engineering Science, Process, Applications," Butterworth-Heinemann 1999, 6th Edition, London.
7. Dieter George E. - Mechanical Metallurgy, McGraw Hill. London, 1988.

Reference Books:

1. Brophy, Rose and Wolff - Thermodynamics of Structure, Vol-II, Wiley Eastern Pvt. Ltd, New Delhi, 1964.
2. Thomas H. Courtney-Mechanical Behavior of Materials-Waveland Press USA, 2005.
3. Anthony Rollett, F J Humphreys, M. Hatherly, Gregory S. Rohrer, Recrystallization and Related Annealing Phenomena, 2004, Elsevier, UK.

T.Y. B.Tech. Metallurgy and Material Technology

Course Name: POWDER METALLURGY

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-1-0-1 = 4	**MSE and TA**	30 and 20
Credits	4	**ESE**	50

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Identify various powder manufacturing processes
2. Explain effect of particle size and shape on compressibility of powders and its sinterability
3. Apply various characterization techniques for phase transformation and properties
4. Analyze sinterability of powders and processing variables
5. Evaluate structure-property of sintered products
6. Design alloy and process cycle for the materials

Syllabus:

Unit	Contents	Lectures
01.	**Characterization and Testing of Metal Powders:** Sampling, Particle Size and Distribution- Sieve Analysis, Light Scattering, Sedimentation, Microscopy and Image Analyzer, Chemical Analysis of Metal Powders, Surface Area, Density and Porosity of Metal Powder, Apparent and Tap Density of Metal Powder, Flow Rate, Compressibility and Green Strength. **Self-study:** ASTM/MPIF standards	**07**
02.	**Production of Metal Powders:** Introduction to Mechanical Processes: Machining, Crushing, Milling, Shotting Graining, Atomization; Physico-Chemical Processes: Condensation, Thermal Decomposition, Reduction, Electrodeposition, Precipitation from Aqueous Solution, Intergranular Corrosion. Electrometallurgy of high purity powders. **Self-study: Mechanical Alloying**	**07**
03.	**Pressing of Metal Powders:** Consolidation of Metal Powder: Powder Conditioning, Cold Die Compaction Techniques, Choice of Tooling System for Die Compaction, Role of Lubrication, Hot and Cold Isostatic Pressing of Metal Powders, Roll Compaction and extrusion of powders, Powder Forging. **Self-study:** Metal Injection Molding- feedstock preparation	**07**

04.	**Sintering:** Types of Sintering processes, Different Mechanisms of Sintering, Liquid Phase Sintering and Activated Sintering, Sinter hardening, Sinterability of ferrous and Al, Cu, Cr, contacts materials, precious metals, diamond cutting tools, HSS tools and carbide tools, magnetic materials; sintering stages of MIM compacts. **Self-study:** Sintering Furnaces, and Furnace Atmospheres	**07**
05.	**High Entropy alloys:** thermodynamics principles in designing of alloys; hard facing alloys for thermal coating /cladding/weld overlay; Powders for additive manufacturing of Engineering and biomedical components, and Secondary operations such as surface hardening treatment, Heat treatment and microstructural transformations, machinability **Self-study:** Additive Manufacturing	**07**
06.	**Sustainable process and circular economy:** extraction of metal powders, recycle and reuse of wastes, Case studies on Bearing Materials, Tool Materials, Ferrites, Cermet, Friction Materials, Medical and Dental Applications, Nuclear and Automotive Applications **Self-study: Re**cycling of materials Policy	**07**

Suggested learning resources:

Textbooks:

1. Anish Upadhyaya and G S Upadhyaya, "- Powder Metallurgy Technology", University Press, 2011.
2. Randall M German, "Powder Metallurgy and Particulate Materials Processing" MPIF, 2005

Reference Books:

1. Powder Metallurgy, ASM Handbook, Vol.7,1984.
2. Randall M German, "Sintering Theory and Practices", John Wiley and Sons,1996

T.Y. B.Tech. Metallurgy and Material Technology

Course: SURFACE PROCESSING OF MATERIALS

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-1-0-1 = 4	**MSE and TA**	30 and 20
Credits	4	**ESE**	50

Course Outcome:

At the end of course students will be able to

1. Understand different surface engineering methods like coatings, treatments, and deposition processes, and know where they are used in real-life industries.
2. Choose the right surface treatment for a given material or application and explain how it improves performance based on structure and properties.
3. Test and evaluate the quality of surface coatings using tools like SEM, profilometers, and wear testers to check thickness, bonding, and surface behavior.

Syllabus:

Unit	Contents	Lectures
01.	**Introduction to Surface Engineering and Modification:** Definition and significance of surface engineering, Historical evolution and modern applications, Classification: Surface coatings vs. surface treatments, Surface degradation mechanisms: wear, corrosion, oxidation, etc. Effect of manufacturing processes on surface properties, Application-specific challenges: 3D surfaces, internal surfaces, powder metallurgy parts. **Self-study:** Scope of surface engineering in improving functional performance.	**07**
02.	**Surface Preparation and Cleaning** Role of substrate characteristics, surface finish, and cleanliness, Types of contaminants and their sources, Mechanical cleaning: abrasive blasting, brushing, Chemical cleaning: acid/alkali cleaning, solvent cleaning, Electrolytic and ultrasonic cleaning techniques, Pretreatment techniques prior to coating or surface modification **Self-study:** Criteria for selection of cleaning methods for ferrous and non-ferrous alloys.	**07**

03.	**Thermo-Chemical and Electrochemical Surface Treatments** Hot-dip coatings: galvanizing, aluminizing, tinning – principles, structures, industrial practices, etc. Electroplating: principles, setup, bath composition, Electroless plating: Ni, Cu, Au and their alloys – process and applications, Multi-layer and alloy plating techniques, Chemical conversion coatings: phosphating, anodizing, chromating – mechanisms and practices. Thermal Spray Coating: principles, materials, industrial practices. **Self-study:** Thermo-chemical treatments: carburizing, nitriding, carbonitriding, cyaniding, boronizing.	**07**
04.	**Vapor Phase and Beam-Assisted Surface Modification:** Physical Vapor Deposition (PVD): evaporation, sputtering, arc deposition, Chemical Vapor Deposition (CVD): conventional and plasma-assisted, Ion implantation and ion beam-assisted deposition, Pulsed laser surface modification, Comparison of different deposition processes: advantages, limitations, and applications. **Self-study:** Case studies of coating design for industrial applications	**07**
05.	**Advanced Coating Techniques and Thin Film Engineering:** Thin film nucleation and growth: Volmer-Weber, Frank–van der Merwe, Stranski–Krastanov models, Techniques: ALD, MBE, Langmuir-Blodgett, spin coating, Inter-diffusion, mass transport, and reactions in thin films, Microencapsulation and hybridization in nanostructured coatings, Nanocoatings: synthesis, structure, and property tuning. **Self-study:** Thin film applications: optical, electrical, magnetic, mechanical properties	**07**
06.	**Characterization and Performance Evaluation of Modified Surfaces:** Surface geometry and morphology: SEM, AFM, profilometry, Coating thickness measurement: stylus, XRF, ellipsometry, Adhesion testing: scratch test, peel test – conventional and recent methods, Mechanical testing at macro, micro, and nano scale, Tribological testing: friction, wear, lubrication (macro to nano-scale), Simulation of real-world applications in tribometers, Corrosion and environmental resistance testing **Self-study:** Simulation of real-world applications in tribometers, Corrosion and environmental resistance testing	**07**

Suggested learning resources:

Textbooks:

1. Modern Surface Technology, Friedrich-Wilhelm Bach et al., Wiley-VCH, 2006
2. Surface Engineering, H. Dimigen et al., Wiley-VCH, 2000.
3. Surface Engineering: An Introduction, J. B. Hudson, et al., Butterworth Heinemann, 2000.
4. Materials Science of Thin Films, M. Ohring, Academic Press, 2002
5. ASM Handbook, Volume 5: Surface Engineering, ASM International, 1995

Reference Books:

1. Surface Engineering & Heat Treatment- Past, present and Future, Edited by P. H. Morton, Published by The Institute of Metals, London, 1991
2. K.L. Chopra, Thin Film Phenomena, McGraw Hill.
3. R.F. Bunshah, Deposition Technologies for Films and Coatings, Noyes Publications
4. J. Takadoum, Nanomaterials and Surface Engineering, Wiley
5. B. Bhushan, Introduction to Tribology, John Wiley & Sons

T.Y. B.Tech. Metallurgy and Material Technology

Course: ENERGY MATERIALS

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-1-0-1 = 4	**MSE and TA**	30 and 20
Credits	4	**ESE**	50

Course Outcome:

At the end of course students will be able to:

1. Identify methods for manufacturing process for materials
2. Explain the effect of processing parameters on material manufacturing
3. Apply thermodynamic and kinetic principles on development of materials
4. Analyze material processing system for recycle reuse and circular economy
5. Evaluate sustainability of process on energy and carbon footprint
6. Design energy management system for storage, generation and conservation

Syllabus:

Unit	Contents	Lectures
01.	**Nuclear Materials:** Materials Specifications for fuel, cladding, moderator, coolant, shield, pressure vessel; Materials selection influenced by the need for a low capture cross-section for neutrons. Nuclear metallurgy; Structures and properties of materials with special relevance for nuclear power generation: uranium and other actinides, beryllium, zirconium, graphite. Recycle and waste management and disposal. environmental impact; safety. **Self-study:** Basics of uranium and other actinides, beryllium, zirconium, graphite.	**07**
02.	**Hydrogen: Hydrogen Storage alloys;** thermodynamics and kinetics; fuel cell, applications in material processing, carbon footprint; safety and environmental impact; sustainability of process. **Self-study:** production of hydrogen, green, blue and grey hydrogen.	**07**
03.	**Rare earth metals:** Types of raw materials, Extraction process such as fluorides/chlorides/metallothermic reduction and other processes, applications of these metals in ferrous and nonferrous and corresponding phase diagrams and physical metallurgy of alloys, safety and environmental impacts; sustainable process, recycle. **Self-study:** Reuse of waste; mass and energy management and	**07**

	reduction of carbon footprint.	
04.	**Rare earth metals (La, Nd, Ce, Pr and others):** Phase diagrams and physical metallurgy of alloys, processing techniques for magnetic and electronic magnetic materials; thermophysical, electrical and magnetic and mechanical properties. **Self-study:** Extraction techniques for Palladium and Platinum as catalyst in clean energy applications. Application of Ruthenium.	**07**
05.	**Solar Energy materials:** raw materials; Extraction processes, properties of materials, applications in semiconductor for renewal energy. Thermoelectric materials; manufacturing techniques; Figure of merit. Harvesting of waste heat; Hybrid energy systems; Application of thermoelectric to metallurgical processes. **Self-study:** Properties of Solar Energy materials, Seebeck and Peltier effect.	**07**
06	**Metal/nonmetals:** Battery materials; production techniques; power to weight density; clean energy fuel vs fossil fuel; recycle and environmental impact; Current trends in clean energy materials / graphene / ceramic-based systems and their applications. **Self-study**: Materials for batteries and power generation.	**07**

Suggested learning resources:

Textbooks:

1. C.K. Gupta," Materials in Nuclear Energy Applications", CRC Press, 1st Edition 2017.
2. M. Shamsuddin, "Physical Chemistry of Metallurgical Processes", 2020.

Reference Books:

1. Konstantin. I. Popov, Stojan S. Djokic and Branimir N. Grgur, Fundamental Aspects of Electrometallurgy, 2002.

T.Y. B.Tech. Metallurgy and Material Technology

Course: SEMICONDUCTOR DEVICES

Course Code	TY	**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-1-0-1 = 4	**MSE and TA**	30 and 20
Credits	4	**ESE**	50

Course Outcome:

At the end of this course, the students will demonstrate the ability to:

1. Describe the crystal structure, defects, and fundamental properties of semiconductor materials.
2. Explain the physical principles governing dopant diffusion, oxidation, and thin film deposition.
3. Apply materials science principles to analyze interfaces, junctions, and mechanical reliability in semiconductor devices.
4. Evaluate the influence of processing conditions on material behavior and device performance.
5. Select appropriate materials and processing techniques for fabricating semiconductor devices.
6. Assess failure mechanisms and recommend improvements in materials or processes to enhance device reliability.

Syllabus:

Unit	Contents	Lecture
01.	**Semiconductor Materials Fundamentals:** Crystal structures, defects, bonding, intrinsic/extrinsic semiconductors, impact of purity and doping	**07**
02.	**Semiconductor Fabrication Steps:** Silicon wafer processing, oxidation, lithography, doping, metallization, packaging and reliability aspects	**07**
03.	**Diffusion and Solid-State Reactions:** Diffusion mechanisms in semiconductors, Fick's laws, dopant diffusion profiles, defect diffusion	**07**
04.	**Oxidation and Thin Film Formation:** Thermal oxidation, oxide properties, dielectric materials, sputtering, evaporation, film growth modes	**07**
05.	**Interface and Junction Materials Science:** Metallurgical aspects of PN junctions, MOS devices, heterostructures, grain boundaries, contact resistance, I-V and C-V characterization	**07**
06	**Mechanical and Thermal Behavior of Device Materials:** Thermal conductivity, stress and strain in devices, electromigration, delamination, Device Reliability and Failure Analysis, degradation, corrosion, fatigue, materials characterization	**07**

T.Y. B.Tech. Metallurgy and Material Technology

Tutorial: Hands-On and Case-Based Learning Activities: (1 Credit)

- Numerical problems: doping, carrier concentrations, diffusion
- Device modelling and circuit analysis
- Material selection for specific devices
- Case studies (e.g., failure analysis of solar cells)
- Group assignments: impact of defects on devices
- Project presentations: “Materials Behind Modern Devices”

Suggested learning resources:

Textbooks:

1. Sze, Simon M., Yiming Li, and Kwok K. Ng. Physics of semiconductor devices. John wiley & sons, 2021.

Reference Books:

1. Sze, S. M., and Ming-Kwei Lee. 2012. Semiconductor Devices: Physics and Technology. 3rd ed. Hoboken, NJ: Wiley.
2. Tu, K. N., and U. Gösele. 2005. Thin Films: Materials, Technology and Applications. Springer Series in Materials Science. Berlin: Springer.
3. Quirk, Michael, and Julian Serda. 2001. Semiconductor Manufacturing Technology. 2nd ed. Upper Saddle River, NJ: Prentice Hall.
4. Wolf, Stanley, and Richard N. Tauber. 2000. Silicon Processing for the VLSI Era: Volume 1 – Process Technology. 2nd ed. Sunset Beach, CA: Lattice Press.
5. May, Gary S., and Simon M. Sze. 2003. Fundamentals of Semiconductor Fabrication. Hoboken, NJ: Wiley.
6. Mishra, Umesh, and Jasprit Singh. 2007. Semiconductor Device Physics and Design. Dordrecht: Springer.

T.Y. B.Tech. Metallurgy and Material Technology

Course: MATERIALS AND PROCESSES FOR E-MOBILITY

Course Code	IOC	**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	2-0-0-1 = 2	**MSE and TA**	30 and 20
Credits	2	**ESE**	50

Course Outcome:

At the end of this course, the students will demonstrate the ability to:

1. Apply energy and power density, lifespan, safety, cost, performance, and environmental factors to select appropriate battery technologies for EVs.
2. Analyze how the structure and microstructure of battery materials affect their electrical performance.
3. Evaluate hybrid EV configurations and justify choices based on application needs and trade-offs.
4. Apply material properties of rare-earth and alternative magnets to select suitable options for EV applications.
5. Design fabrication processes for EV components, including steps, materials, and quality control.

Syllabus:

Unit	Contents	Lectures
01.	**Introduction to e-Vehicles and Battery Fundamental:** Types of e-vehicles; Comparison with IC engines; Life cycle analysis and raw material needs; Battery economics and value chain; Concepts of energy and power density; Comparison of Li-ion, Na-ion, and other battery chemistries.	**06**
02.	**Li-ion Battery Materials and Manufacturing**: Structure of Li-ion batteries: cathode, anode, electrolyte, separator, binder; Performance and selection of materials; Electrolyte synthesis, microstructure, and testing; Cell fabrication and integration; Solid-state batteries.	**06**
03.	**Battery Packs, BMS, Supercapacitors, and Fuel Cells:** Battery pack design: insulation, sealing, thermal management; Trade-offs in Li-ion systems; Battery Management Systems (BMS); Supercapacitor basics and materials; **Material testing using cyclic voltammetry**; Fuel cells for EVs; Battery-supercapacitor and battery-fuel cell hybrids.	**06**
04.	**Magnetic, Structural & Sustainable Materials for EVs:** Rare-earth and alternative magnets for motors (Nd, Dy, etc.); Magnet recycling; Structural materials (composites, Al, steel); Materials in charging stations; Sustainable and recyclable materials for EVs and batteries.	**06**

Suggested learning resources:

Textbooks:

1. Richard Folkson, Alternative fuels and advanced vehicle technologies for improved environmental performance: Towards zero carbon transportation, Woodhead Publishing, 1st Edition, 2014
2. M. Ehsani, Y. Gao, S. Longo, K. Ebrahimi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles, CRC Press, 3rd Edition, 2018
3. R. Xiong, S. Weixiang, Advanced Battery Management Technologies for Electric Vehicles, Wiley, 1st Edition, 2019
4. Yu, A., Chabot, V., & Zhang, J. (2013). Electrochemical supercapacitors for energy storage and delivery: fundamentals and applications (p. 383). Taylor & Francis.

Reference Books:

1. Notten, P., H. Bergveld, and W. Kruijt. "Battery management systems: design by modeling." (2002).
2. Brodd, R. J., Kozawa, A., & Yoshio, M. (2009). Lithium-Ion Batteries: Science and Technologies. Springer.
3. J. Jiang, C. Zhang, Fundamentals and Application of Lithium-ion Battery Management in Electric Drive Vehicles, Wiley, 1st Edition, 2019
4. D. Beeton, G. Meyer, Electric Vehicles Business Models: Global Perspectives, Springer, 1st Edition, 2015

T.Y. B.Tech. Metallurgy and Material Technology

Course: INTERNSHIP

Course Code	IOC	**Scheme of Evaluation**	CIE
Teaching Plan	0-0-6-0 = 1		
Credits	1	**ESE: Report and Presentation/Oral Exam**	100

Course Outcome:

At the end of this course, the students will demonstrate the ability to:

1. Students will demonstrate the ability to integrate and utilize their academic learning to solve practical problems during the internship.
2. Students will exhibit enhanced interpersonal and professional skills, contributing effectively to team projects.
3. Students will acquire and demonstrate proficiency in industry-specific tools, technologies, or methodologies relevant to their discipline.
4. Students will apply critical thinking to assess situations, identify problems, and develop innovative solutions within the workplace context.
5. Students will establish meaningful connections within the industry, gaining insights and advice that inform their career development.
6. Students will produce reflective reports or presentations that assess their achievements, challenges faced, and lessons learned during the internship.

Scope of Internship:

Type of Internship to be undertaken either in Industry / R and D labs / Govt Depts/ Education institutes (HEI within 100 NIRF rank)

Some of the indicative areas as per Internship Policy are

a. Education institutes / R and D labs/ Incubation centre / Start-up
b. Reputed industries
c. Economy & Banking Financial Services and Insurance Area
d. Logistics, Automotive & Capital Goods Area
e. Information Technology/Information Technology enabled Services & Electronics Area
f. Handcraft, Art, Design & Music Area
g. Healthcare & Life Science Area
h. Sports, Wellness and Physical Education Area
i. Digitisation & Emerging Technologies
j. Humanitarian, Public Policy and Legal Service Area
k. Food processing industries
l. Sustainable development Area
m. Environment Area
n. Pharmaceutical and textile Industries

T.Y. B.Tech. Metallurgy and Material Technology

Course: PROJECT STAGE-I

Course Code	IOC	**Scheme of Evaluation**	ISE / ESE
Teaching Plan	0-0-4-0 = 2	**ISE**	50
Credits	2	**ESE**	50

Course Outcome:

At the end of this course, the students will demonstrate the ability to:

1. Identify the problem definition of project by analysing the literature review.
2. Design the experiments and its setup to obtain the specific objective of project.
3. Communicate the technical information effectively in both verbal and written forms.

Project Work:

This initial phase focuses on foundational research and planning. (TRL-2: Technology Readiness Level 2 - Concept Formulation) Research Problem Identification, Literature, objective, methodology and Architecture / Plan of work

1. Research Problem Identification:
   - Understanding the chosen problem statement provided.
   - Analyzing its relevance to National Mission / Atmanirbhar Bharat / Industry requirements / Funding body requirements / Socially relevant projects / Sustainable Development Goals (SDGs).
   - Defining the scope and boundaries of the identified problem.
2. Literature Review:
   - Comprehensive study of existing research, solutions, and technologies related to the problem.
   - Identification of gaps in current knowledge or solutions.
   - Citation and referencing of relevant academic papers, reports, and industry documents.
3. Objective Definition:
   - Formulating clear, specific, measurable, achievable, relevant, and time-bound (SMART) project objectives.
   - Defining primary and secondary objectives.
4. Methodology Development:
   - Proposing a detailed approach to address the problem.
   - Outlining the techniques, tools, and resources required.
   - Defining data collection, analysis, and validation strategies (if applicable).
5. Architecture / Plan of Work:
   - Developing a high-level architectural design or conceptual framework for the proposed solution.
   - Creating a detailed project plan with milestones, timelines, and task assignments for the entire project duration (1.5 years).
   - Defining roles and responsibilities within the student group.

The end semester evaluation shall be based on project work in power point presentation and a project report.

Self-Study: online / offline materials on IPR, technical paper writing, plagiarism, safety, NDA, Regulatory standards, for example- BIS, etc.

T.Y. B.Tech. Metallurgy and Material Technology

SEMESTER VI

Course: TRANSPORT PHENOMENA

Course Code		Scheme of Evaluation	MSE, TA and ESE
Teaching Plan	2-1-0-1 = 3	MSE and TA	30 and 20
Credits	3	ESE	50

Course Outcome:

At the end of course students will be able to:

1. Understand different types of fluids and apply appropriate equations to solve fluid flow problems.
2. Understand various parameters of a chemical reaction such as rate, order molecularity and rank various theories applied to slag-metal interfacial mass transfer.
3. Analyze difference between laminar and turbulent flow and evaluate various parameters in metallurgical processes.
4. Identify the processes in which steady state and unsteady state thermal conduction is prevalent and evaluate the rate of thermal conduction.
5. Evaluate the rate of convective heat transfer and understand the difference between natural convection and forced convection.
6. Evaluate the rate of radiative heat transfer in different processes and assess the operative mode(s) of heat transfer in a process.

Syllabus:

Unit	Contents	Lectures
01.	**Characterization of Fluids:** Viscosity of liquid metals, slags, gases, molten salts and polymers, Momentum balance, Equation of continuity and the momentum equation, Navier - Stokes's equation, Creeping flow around a solid sphere, Stoke's law application. **Self-Study:** Types of fluid flow, Classification of fluids.	06
02.	**Friction factors,** Dimensional analysis for friction factors, Flow past submerged bodies, Flow through reactors, Energy balance, Bernoulli's theorem: Flow through ladles, Flow measurements. **Self-study:** Applications of Bernoulli's theorem.	06
03.	**Steady state thermal conduction** - Fourier's law, Critical thickness of insulation, Steady state conduction and unsteady state thermal conduction: Lumped heat capacity approach, finite, semi-infinite and infinite systems, Heisler charts. **Self-study:** Introduction to various modes of heat transfer, Steady state heat conduction with heat generation, unsteady state thermal conduction.	06

04.	**Convective Heat Transfer:** Concept of velocity and thermal boundary layer, natural and forced convection of metallic materials with different configurations, Significance of various dimensionless numbers in quenching and their explanation with dimensionless analysis – Buckingham π theorem, Heat transfer coefficient in various metallurgical systems and processes e.g. quenching, forging, packed bed reactor, fluidized bed reactor, Convective heat transfer in solidification of melts and application of Chvorinov's rule. **Self-study:** Buckingham π theorem, Chvorinov's rule, case studies	**06**
05.	**Radiation Heat Transfer:** Principles of radiation heat transfer, Terms in radiation, Radiation heat transfer between black bodies, non - black bodies, radiation shape factors, shape factor algebra, Interchange factor, Radiation heat transfer in furnaces, Few real life examples wherein all the modes of heat transfer are operative such as operation of fuel cells, curing of thermosetting polymers, heat loss through human body etc. **Self-study:** Laws of radiation, Emissivity, black bodies, non - black bodies	**06**
06	Rate constant, elementary & complex reactions, Rate limiting steps. Concept of activation energy, Unsteady state mass transfer, differential formulation of mass transfer, Convective mass transfer and concept mass transfer coefficient, Theories of mass transfer dealing with slag-metal interface. **Self -study:** Application of kinetics (Arrhenius equation), Theories of reaction rates – simple collision theory, activated complex theory.	**06**

Suggested learning resources:

Textbooks:

1. T.L. Bergman, A.S. Lavine, F.P. Incropera, D.P. Dewitt, Fundamentals of Heat and Mass Transfer, 7th Edition, 2012, John Wiley and Sons.
2. D.R. Gaskell, An introduction to Transport Phenomena in Materials Engineering, 2nd Edition,2012, Momentum Press.

Reference Books:

1. D.R. Poirier, G.H. Geiger, Transport Phenomena in Materials Processing, 1st Edition, 1994,
2 The Minerals, Metals and Materials Society (2016 Reprint by Springer Int. Publishers)

3. A.K. Mohanty, Rate Processes in Metallurgy, 1st Edition, 2009, Prentice Hall of India.
4. R.B. Bird, W.E. Stewart, E.N. Lightfoot, Transport Phenomena, 2nd Ed., John Wiley & Sons., 2002.
5. J. Welty, C.E. Wicks, R.E. Wilson, G.L. Rorrer, Fundamentals of Momentum, Heat and MassTransfer, 5th Edition, 2007, John Wiley and Sons.
6. O. Levenspeil, Engineering Flow and Heat Exchanges, 3rd Edition, 2014, Springer.
7. J.P. Holman, Heat Transfer, 10th Edition, 2010, McGraw Hill Higher Education.
8. S. Kou, Transport Phenomena and Materials Processing, 1st Ed., 1996, John Wiley and Sons.
9. J. Szekely, N.J. Themelis, Rate Phenomena in Process Metallurgy, 1st Ed., 1971, Wiley Interscience.

T.Y. B.Tech. Metallurgy and Material Technology

Course: IRON AND STEEL MAKING

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of course students will be able to:

1. Understand the various processes involved in making Pig Iron, Ferro Alloys and DRI for steel production.
2. Understand physicochemical reactions that are taking place in production of Iron and steel.
3. Analyze impact of input raw material on refractory selection.
4. Analyze impact of de-oxidation, vacuum degassing and casting technology on
5. production of sound casting suited for engineering applications.
6. Evaluate suitable process routes for making sound and clean steel.
7. Analyze process parameters and improve reaction kinetics and sustainability.

Syllabus:

Unit	Contents	Lectures
01.	**History of Integrated and Mini Steel Plants in India**: Indian steel scenario as at present and Principles guiding Steel Plant location. Pig iron, Direct Reduced Iron and Blast furnace production, Ferro alloy production. **Self-Study:** Blast furnace irregularities and remedial measures.	**06**
02.	**Physical Chemistry of Iron and Steel Making:** Thermodynamic and Kinetics of Refining Reactions, Carbon Reaction, Phosphorus Reaction, Sulphur Reaction, Silicon Reaction, Refining Slags and its properties, Importance and Mechanism of Decarburization Reaction, Reaction at Slag Metal interface. **Self-study:** Ternary diagram of slag system.	**06**
03.	**Basic Oxygen Steel Making:** BOF practice, Equipment, Operation and Process, slag Metal reactions in B.O.F., Raw material and flux practices, Modifications and further Development in Conventional BOF, Oxygen Lance: Design, Construction and Operation, Top and Bottom Blow processes, its advantages and disadvantages. **Self-study:** Submerged arc melting for Ferro alloys.	**06**

T. Y. B. Tech. Metallurgy and Materials Technology

04.	**Electric Steel Making:** Details of Electric Arc Furnaces, Its Variations, Sequence of EAF Operations, Various additions at Different Stages, Slag Control, UHP Arc Furnaces, Arc Furnace practices for Carbon and Low Alloy Steels. **Self-study:** Plasma electric arc furnace.	**06**
05.	**Secondary Steel Making Processes:** Ladle Furnaces (L.F.), Vacuum Systems and Vacuum treatment of Steel, Gases in steel, LF-VD processes and AOD, VOD, VAD techniques, R-H degassers, Ladle Stirring and its Advantages, ESR-Principle and Technology, Deoxidation –Theory and practice, Floatation's of products, Modifications of Inclusions. **Self-study:** Injection Metallurgy. Types of inclusions	**06**
06	**Continuous Casting (C.C.) and Ingot Casting:** **Ingot Casting:** Types of Moulds, Advantages and Disadvantages, Ingot Defects and Remedies, **Continuous casting:** C.C. machines with its various units and types C.C. of Blooms, Slabs and Thin slabs EM S of Moulds, Reoxidation prevention methods during Steel Casting, Advantage of C.C. **Self-study:** Environmental issues related to Steel Making. Strip casting, horizontal continuous casting, rapid solidification.	**06**

Suggested learning resources:

Textbooks:

1. R. H. Tupkary, V. R. Tupkary, An Introduction to Modern Steelmaking, 7thEdition, Khanna Publications, Delhi, 2012.
2. Ahindra Ghosh, Amit Chatterjee Iron and Steel making: Theory and practice, 2ndEdition, PHI learning Pvt. Ltd, New Delhi, 2011.

Reference Books:

1. Darken and Gurry- Physical Chemistry of Metals, McGraw Hill, 1953.
2. Irving, William R. Continuous casting of steel. CRC Press, 2024.

T. Y. B. Tech. Metallurgy and Materials Technology

Course: FOUNDRY TECHNOLOGY

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of course students will be able to:

1. Understand the casting processes and select appropriate patterns and moulds to make a desired casting.
2. Evaluate and substantiate the role of sand and sand additives in the production of sound castings.
3. Apply appropriate molding and casting techniques to produce the desired casting.
4. Understand principles of various furnaces and apply knowledge to select appropriate furnaces.
5. Analyze the effect of solidification technique on the microstructure and properties of alloy
6. Understand the root cause of a casting defect and provide preventive and remedial solutions.

Syllabus:

Unit	Contents	Lectures
01.	Basic sand-casting process, pattern, mold, core, gating, riser, casting yield, Classification of casting processes, Patterns and Cores – Selection of parting line, allowances on pattern, pattern materials, color coding, core plates, core-boxes, design of core print, chaplets. **Self-study:** Types of Foundries, General layout and sections in foundries.	**07**
02.	Mold making - green sand molding, dry sand molding, molding sands, mould compaction machines, high pressure molding, sand slinger, refractory coatings, Venting, molding boxes, chills, roll of additives & technical terms in sand like total clay, active clay, latent clay, dead clay. Sand reclamation. **Self-Study:** Properties of foundry sands and their testing, additives, Sand Control, core sands, Jolt-squeeze molding machine.	**08**
03.	Special molding and casting processes - CO_2-Silicate process, Core making- Introduction to modern core sand binders like, hot box, cold box, ester & Shell molding, Evaporative Pattern (EPC) and Vacuum-sealed (V-) processes, Plaster mould, Ceramic mould, Investment casting, die casting process – gravity die, pressure die, low pressure die and squeeze casting. Introduction to additive	**08**

	manufacturing for Mold and core making. **Self-study:** Casting quality improvement by Mold and Core coatings, their significance in getting satisfactory quality, Testing of coatings.	
04.	Melting furnaces – Cupola and its types, Cupola charge calculations, chill testing of C.I., Rotary furnace, Induction furnace, Arc furnace, holding furnaces, inoculation, fluxes, degassing, use of vacuum, de-oxidation practices in steel and cast-iron foundry, converters for SG iron making. **Self-study:** Refractories used in Foundry, Melt fluidity and testing.	**09**
05.	Solidification of metals and alloys, Directional Solidification, Constitutional super-cooling, Segregation, Modes of solidification - planner, cellular, dendritic mode, Casting feeding – shrinkage, riser and chills, Cain's formula, NRL method, Inscribed circle method, modulus method, padding, Gating systems- fluid flow, Pressurized and non-pressurized gating systems, metal filtration, Software for casting process. **Self-study:** long freezing range and short freezing range alloys, Materials used for vacuum impregnation seals, study of properties of various cast alloy.	**08**
06	Shake out, cleaning, fettling, finishing and heat treatment of casting, Casting design, Quality control and assurance, Casting evaluation, Inspection and testing of castings. Aluminum alloy, Magnesium alloy, copper alloy and special alloy foundry practice. Industry 4.0 and Digital Foundry. **Self-study:** Nature and causes of Casting defects, their remedial measures, salvage of defective castings.	**08**

Suggested learning resources:

Textbooks:

1. P.L. Jain- Principles of Foundry Technology, 5th edition, Tata-McGraw-Hill, New Delhi, 2017.
2. A.K. Chakrabarti, Casting Technology and cast alloys, Prentice-Hall of India, 2022
3. R.W. Hiene, C.R. Loper and P.C. Rosenthal, Principles of Metal Casting, Tata-McGraw-Hill, Reprint 1998.

Reference Books:

1. Peter Beeley, Foundry Technology, 2nd edition, Butterworth-Heinemann, Oxford, 2001.
2. ASM Handbook, Vol. 15, ASM International, OH, USA.
3. Campbell, John. Complete casting handbook: metal casting processes, metallurgy, techniques and design. 2nd edition, Butterworth-Heinemann, 2015.

T. Y. B.Tech. Metallurgy and Material Technology

Course: FOUNDRY TECHNOLOGY LABORATORY

Course Code		Scheme of Evaluation	ISE and ESE
Teaching Plan	0-0-2-0 = 1	ISE	50
Credits	1	ESE (Oral)	50

Course Outcome:

At the end of the laboratory course, the students will demonstrate the ability to:

1. Evaluate the characteristics of prepared sand for various casting techniques.
2. Understand the pattern and core design to produce a sound casting
3. Evaluate mechanical and physical properties of produced casting.

List of Experiments: (Any 08 experiments)

1. Performing Sand cleaning, conditioning and blending.
2. Determine AFS grain fineness number by using Sieve shaker.
3. Find Moisture content, Mould ability, Flow ability.
4. Experiment on melting in Muffle or Induction furnace and produce a casting from the molten metal.
5. Demonstrate Pattern and core making, preparation of core sand and it's testing e.g. Hardness, Flow ability, Mould ability etc.
6. Performing Friability Test and mold hardness
7. Performing Fluidity Test.
8. Virtual Casting Simulation Experiment using open-source software.
9. Study of casting quality improvement / alloy development techniques through peer reviewed paper.
10. Visit to at least one foundry around Pune.

T. Y. B.Tech. Metallurgy and Material Technology

Course: MATERIALS SOFTWARE TOOLS LABORATORY

Course Code		**Scheme of Evaluation**	ISE and ESE
Teaching Plan	0-0-2-1 = 1	**ISE**	50
Credits	1	**ESE**	50

Course Outcome:

At the end of course students will be able to

1. Apply various software tools for plotting, analyzing and processing the data obtained from various experiments.
2. Use models and simulation tools to predict the results.
3. Correlate structure property relationship

List of Experiments

1. Use of ImageJ software for the Calculation of Phase Fraction of at least 3 microstructures by the Threshold Adjustment Method, Area measurement method in Microstructures of metals and alloys.
2. Use of ImageJ software for Counting of Pores, Carbides, second phase particles, Blow Holes, Grain Size Measurement in at least 3 Microstructures.
3. Electronic Band Structure and Structural Analysis Using VASPKIT
4. Modelling of Crystal Structure and Simulation of XRD Pattern Using VESTA Software
5. Calculating a Binary or ternary Phase Diagram for a Metallic System using Thermo-Calc Software.
6. Use of ATEX software for Plotting and analysis of EBSD Data and extracting microstructural information like – Grain Boundary Area, Grain Orientation Map, Grain Boundary Character Distribution
7. Use of Matlab Modules to find the Solution of Heat Transfer Problem.
8. Use of Matlab Modules for the optimization of Multiobjective problems
9. Data Plotting, Curve Fitting, Regression analysis using suitable Software
10. Plotting of 2D and 3D data, Contour Maps, Pie Chart, etc. using Microsoft Excel or any suitable software
11. Simulation of Casting Processes using Click-to-Cast Software or any suitable software
12. Use of FEM Based Solver to simulate deformation/phase transformation of metals and alloys.

T. Y. B.Tech. Metallurgy and Material Technology

Course: MATERIALS JOINING

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-1-0-1 = 4	**MSE and TA**	30 and 20
Credits	4	**ESE**	50

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Classify joining processes and describe various heat sources in welding, including electric arc, chemical, and contact resistance sources.
2. Explain fusion welding techniques such as SMAW, TIG, MIG, laser beam, and electron beam welding.
3. Analyse heat and mass transport in welding using Rosenthal's equations and study fluid flow in arcs and weld pools.
4. Evaluate welding parameters affecting temperature distribution, solidification behaviour, and microstructural changes in the weld and HAZ.
5. Analyse welding defects, their mechanisms, and methods for prevention.
6. Apply solid-phase and hybrid joining techniques for metals and non-metals, and design suitable processes for various applications.

Syllabus:

Unit	Contents	Lectures
01.	**Fundamentals of Joining:** Classification of Joining Processes, Heat Sources in Welding, Electric Arc, its Structure, Characteristics and Power, Metal Transfer and Mass Flow, Chemical Heat Source, Contact Resistance Heat Source	**06**
02.	**Materials Joininig processes:** Fusion Welding, Oxyacetylene Welding, Shielded Metal Arc Welding, TIG Welding, MIG Welding, Plasma Arc Welding, Flux-Core Arc Welding, Submerged Arc Welding, Electro Slag Welding, Electron Beam Welding, Laser Beam Welding, Thermit Welding.	**06**
03.	**Heat and mass transport in Joining:** Heat Source, Efficiency, Heat Flow in Welding, Rosenthal"s Two-Dimensional and Tree Dimensional Equations, Effect of Welding Parameters, Fluid Flow in Arcs, Fluid Flow in Weld Pool, Metal Evaporation.	**08**
04.	**Solidification and Chemical Reactions in Welding: Fusion Zone,** Solidification, Effect of Cooling Rate, Partially Melted Zone, Liquation, Heat Affected Zone, Chemical reactions between Gas-Metal, Slag-Meta, Metal Evaporation	**08**

05.	**Defects in Welded Joints:** Classification of welding defects, Micro-Segregation, Macro-Segregation, Banding, Gas Porosity, Inclusions, Weld Metal Cracking, Liquation Cracking, Hydrogen Cracking. Residual Stresses, Distortion, Fatigue of Welded Joints.	**06**
06	**Principles of Solid Phase Welding**: Diffusion Welding, Forge Welding, Butt Welding, Flash Butt Welding, Spot Welding, Projection Welding, Seam Welding, Ultrasonic Welding, Explosion Welding, Principles of Solid/Liquid State Joining, Friction Stir Welding, Joining of Non-Metallic Materials: Joining of polymers, ceramics, polymer – metals, ceramic – metals, polymer – ceramics and composite materials, Soldering and Brazing, Adhesive Bonding.	**08**

Suggested learning resources:

Textbook:

1. A.Ghosh and A. K. Mallik, "Manufacturing Science" ,2nd Ed., Affiliated East-West Press Private Limited, New Delhi, 2010
2. Sindo Kou, " Welding Metallurgy", 2nd ed, John Wiley Hoboken 2003.
3. J.F. Lancaster, "Metallurgy of Welding", 6th Ed., Woodhead Publishing Series in Welding and other Joining Technologies 1999
4. Robert D. Messler Jr., "Principles of Welding Processes", Physics Chemistry and Welding 2nd Ed., Wiley – VCH 2004

Reference Book:

1. ASM Metals Handbook: Welding and Joining, Vol. 6, 9th Ed., ASM Metals Park Ohio 2011

T. Y. B.Tech. Metallurgy and Material Technology

Course: NON-DESTRUCTIVE TESTING and CHEMICAL CHARACTRIZATION

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-1-0-1 = 4	**MSE and TA**	30 and 20
Credits	4	**ESE**	50

Course Outcome:

At the end of course students will be able to

1. Define and demonstrate basic knowledge and comparison of the NDT methods.
2. Select and apply suitable method for testing and evaluation.
3. Identify application areas of the various methods and their limitations and recommendations.
4. Analyze and evaluate results of various testing methods.
5. Design and develop NDT methods, simulation methods and their use.

Syllabus:

Unit	Contents	Lectures
01.	**Introduction of NDTs** Introduction: Testing and its types, Brief description about NDE/NDT (Scope, advantages, limitations, and applications), Role of NDT in quality control, Basic principles, evaluation, advantages, limitations and applications of visual optical methods, dye penetrate testing, visual inspection. **Self-study:** NDT codes and standards, NDT-related competencies: Non-destructive testing Qualification and certification of NDT personnel (ISO 9712:2012).	**03**
02.	**Magnetic testing (MT) and Eddy current testing (ECT)** Types of MT & ECT, Testing procedures and equipment, Applicable standards & acceptance criteria, Factor affecting MT & ECT, Advantages, limitations, and applications. **Self-study:** Basic theory of magnetism, Magnetization & demagnetization methods, Self and mutual inductance, Skin effect.	**06**

03.	**Radiographic testing (RT), Ultrasonic Testing (UT) and Acoustic Emission Testing (AET)** Principles, Inspection procedures and equipment for RT, UT and AET, Type of display and display system, Applicable standards & acceptance criteria, Factors affecting RT, UT and AET, Advantages, limitations, and applications, Effect of radiation in film, radiographic imaging, image formation, image quality, image interpretation, **Self-study:** Radiation sources, ultrasonic transducers Generation of ultrasound, sources of acoustic emission.	**06**
04.	**Spectroscopic Techniques** UV-Vis Spectroscopy, Infrared Spectroscopy (FTIR), Raman Spectroscopy: Complementary to IR, Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma (ICP-OES & ICP-MS): Multi-element analysis, detection limits. **Self-study:** Background of Spectroscopy	**06**
05.	**X-ray-Based Techniques** X-ray Fluorescence (XRF), X-ray Photoelectron Spectroscopy (XPS), Energy Dispersive X-ray Spectroscopy (EDS), Wavelength Dispersive X-ray Spectroscopy (WDS), Secondary Ion Mass Spectrometry (SIMS), Surface preparation, Depth profiling. **Self-study:** Generation of primary X-rays beam, Signal generation in electron beam-material interaction.	**06**
06.	**Electrochemical Techniques and Thermal Analysis** Electrochemical Impedance spectroscopy of liquids and solids, Gamry Potentiometry, Voltammetry, Electrochemical cell, EMF cell, Electrode potential. Basic principles and applications of thermogravimetry analyzer (TGA)/differential thermogravimetry analysis (DTG), Differential thermal analyzer (DTA), Differential scanning calorimeter (DSC), Dilatometer, gas chromatography. **Self-study:** Concepts in corrosion mechanism	**09**

Suggested learning resources:

Textbooks:

1. Baldev Raj, T. Jayakumar, M. Thavasimuthu, Practical Non-Destructive Testing, 3rd Ed., Narosa.
2. Prasad, C.G.K. Nair, Non-Destructive Testing and Evaluation of Materials, Tata MacGraw Hill
3. Bhim Prasad Kaflé, Chemical Analysis and Material Characterization by Spectrophotometry, Elsevier, 2019.

4. Irene Mueller-Harvey, Richard M Baker, Chemical Analysis in the Laboratory, A Basic Guide, Royal Society of Chemistry, 2007.

Reference Books:

1. B. Hull, Non-Destructive Testing, Springer.
2. ASM Metals Handbook, Non-Destructive Evaluation and Quality Control, Vol. 17, 9th Edition
3. Louis Cartz, Nondestructive Testing, ASM International
4. Paul E.Mix, Introduction to Nondestructive Testing: A Training Guide, 2nd Edition, Wiley Publication.

T. Y. B.Tech. Metallurgy and Material Technology

Course: ADVANCED COMPOSITE MATERIALS

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-1-0-1 = 4	**MSE and TA**	30 and 20
Credits	4	**ESE**	50

Course Outcome:

At the end of course students will be able to

1. Understand the classification and structure of various advanced composite systems.
2. Apply composite material concepts in thermal, electrical, and electromagnetic applications.
3. Analyze and design thermoelectric and dielectric composites for targeted functionality.
4. Evaluate composite systems in optical, magnetic, biomedical, and energy applications.
5. Develop independent learning skills through focused self-study on emerging topics.
6. Integrate interdisciplinary knowledge to solve complex engineering problems using composites.

Syllabus:

Unit	Contents	Lecture
01.	**Fundamentals and Matrix-Based Classification** Introduction to composites and their applications, classification based on matrix materials – polymer, metal, carbon, ceramic, cement, reinforcement forms – continuous and discontinuous, fabrication methods for each matrix type, microstructure and property correlation, interface behavior and bonding mechanisms **Self-study Topics:** Interface engineering in polymer-matrix composites, wetting behavior in metal-matrix composites	**08**
02.	**Thermal Applications of Composite Materials** Thermal conductivity mechanisms in composites, role of high thermal conductivity fillers – graphite, diamond, ceramics, metal-matrix composites for heat dissipation, carbon and ceramic-matrix composites for thermal applications, thermal interface materials (TIMs), thermal insulation and heat retention strategies **Self-study Topics:** Graphite-based composites for thermal management, ceramic-matrix composites for high-temperature insulation	**08**

03.	**Electrical and Electromagnetic Applications** Electrical conductivity in composites, polymer- and ceramic-matrix composites in electrical systems, continuous and discontinuous filler influence, EMI shielding mechanisms, composites for microelectronics and resistance heating, radar-absorbing and antistatic materials **Self-study Topics:** Conductive behavior of polymer-based composites, design of EMI shielding polymer composites	**08**
04.	**Thermoelectric and Dielectric Composites** Thermoelectric effect and property tailoring using composites, structural and non-structural thermoelectric materials, piezoelectric and pyroelectric behavior, dielectric properties – constant, loss, strength, composites for capacitors and insulation, fiber and filler influence on thermoelectric performance **Self-study Topics:** Fiber selection in thermoelectric composites, high-permittivity composites for capacitors	**08**
05.	**Optical, Magnetic, and Electrochemical Applications** Optical behavior in composites, waveguides, filters, laser materials, magnetic properties – ferromagnetic, ferrimagnetic, magnetoresistive, magnetostrictive behavior, metal-, ceramic-, and polymer-matrix magnetic composites, composites for electrodes in batteries, fuel cells, and supercapacitors **Self-study Topics:** Magnetoresistive composites for sensors, carbon-matrix composites in lithium-ion batteries	**08**
06.	**Smart, Biomedical, and Damping Composites** Smart composite systems for strain, damage, and temperature sensing, vibration damping behavior in polymers, metals, and ceramics, biocompatibility of composite systems, biomedical applications – implants, scaffolds, dental uses, multifunctionality and integrated performance **Self-study Topics:** Smart polymer composites for damage sensing, bioceramic composites for orthopedic implants	**08**

Suggested learning resources:

Textbooks:

1. D. D. L. Chung, Composite Materials: Science and Applications, Springer, 2nd ed., 2010.
2. K. K. Chawla, Composite Materials: Science and Engineering, Springer, 2012.

Reference Books:

1. R. W. Cahn, *Composite Materials*, VCH, 1990.
2. D. Gay, S. V. Hoa, S. W. Tasi, *Composite Materials: Design and Applications*, CRC Press, 2003.

T. Y. B.Tech. Metallurgy and Material Technology

Course: EV MATERIALS

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-1-0-1 = 4	**MSE and TA**	30 and 20
Credits	4	**ESE**	50

Course Outcome:

At the end of this course, the students will demonstrate the ability to:

1. Apply criteria like energy density, safety, cost, and lifespan to select suitable battery technology for a given EV application.
2. Analyze how the structure and microstructure of battery components affect electrical performance.
3. Evaluate hybrid vehicle configurations and recommend options based on performance trade-offs and application needs.
4. Apply material properties of magnets to select suitable types for EV use, considering cost, performance, and availability.
5. Design fabrication processes for EV components, specifying steps, materials, and quality control.

Syllabus:

Unit	Contents	Lectures
01.	**Introduction to e-Vehicles:** Types of e-vehicles; Comparison with IC engines; Life cycle analysis; Battery economics; Raw material availability; Energy & power density concepts; Comparing battery chemistries (Li-ion, Na-ion, supercapacitors) using basic data.	**07**
02.	**Li-ion Battery Materials:** Structure: cathode, anode, electrolyte, separator, binder; Key properties and functions of each part; Electrolyte synthesis and testing; Solid-state batteries; Basics of battery recycling and associated challenges	**07**
03.	**Battery Packs and BMS:** Cell to pack design; Insulation and sealing materials; Thermal management; Trade-offs in battery performance vs. cost and safety; Calculating cell and pack capacities; Battery Management Systems (BMS); New chemistries (Na-ion, Zn-ion, Li-S, metal-air, Ni-based).	**07**
04.	**Supercapacitors & Fuel Cells: Working principle and materials: carbon-based, metal oxides, conductive polymers; Electrolytes and collectors; Material testing using cyclic voltammetry; Battery-supercapacitor and battery-fuel cell hybrid systems.**	**07**
05.	**Magnets, Motors & Sustainable Materials :** Rare-earth (Nd, Dy, Tb) and rare-earth-free magnets; Magnet recycling; Structural materials for EV bodies (composites, aluminum, steel); Charging station materials; Sustainable, recyclable, and green materials; Indian policies on battery materials.	**07**

06.	**Characterization & Sustainability:** Basics of mechanical, electrical, thermal, and electrochemical testing (CV, galvanostatic cycling); Non-destructive testing (NDT); Design for disassembly and recycling; Environmental and economic impacts of e-mobility.	**07**

Tutorial: Hands-On and Case-Based Learning Activities: (1 Credit)

1. Microstructure–performance correlation using SEM/XRD/EDS datasets
2. Analysis of CV plots for identifying battery/supercapacitor materials
3. Research survey on recent status of Na-ion, Zn-ion, and Ni-based batteries
4. Project based on learning conceptual design of a hybrid powertrain (battery + fuel cell/supercapacitor)

Suggested learning resources:

Textbooks

1. Richard Folkson, Alternative fuels and advanced vehicle technologies for improved environmental performance: Towards zero carbon transportation, Woodhead Publishing, 1st Edition, 2014
2. M. Ehsani, Y. Gao, S. Longo, K. Ebrahimi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles, CRC Press, 3rd Edition, 2018
3. R. Xiong, S. Weixiang, Advanced Battery Management Technologies for Electric Vehicles, Wiley, 1st Edition, 2019
4. Yu, A., Chabot, V., & Zhang, J. (2013). Electrochemical supercapacitors for energy storage and delivery: fundamentals and applications (p. 383). Taylor & Francis.
5. Kanamura, K. (Ed.). (2021). Next generation batteries: realization of high energy density rechargeable batteries. Springer Nature.

Reference Books

1. Notten, P., H. Bergveld, and W. Kruijt. "Battery management systems: design by modeling." (2002).
2. Yang, S., Liu, X., Shen, L., & Zhang, C. (2023). Advanced Battery Management System for Electric Vehicles (Vol. 1). Springer.
3. Brodd, R. J., Kozawa, A., & Yoshio, M. (2009). Lithium-Ion Batteries: Science and Technologies. Springer.
4. J. Jiang, C. Zhang, Fundamentals and Application of Lithium-ion Battery Management in Electric Drive Vehicles, Wiley, 1st Edition, 2019
5. D. Beeton, G. Meyer, Electric Vehicles Business Models: Global Perspectives , Springer, 1st Edition, 2015.

T. Y. B.Tech. Metallurgy and Material Technology

Course: PROJECT STAGE-II

Course Code	IOC	**Scheme of Evaluation**	ISE / ESE
Teaching Plan	0-0-4-0 = 2	**ISE**	50
Credits	2	**ESE**	50

Course Outcome:

At the end of this course, the students will demonstrate the ability to:

1. Identify the problem definition of project by analysing the literature review.
2. Design the experiments and its setup to obtain the specific objective of project.
3. Communicate the technical information effectively in both verbal and written forms.

Project Work:

The work focuses on the Continuation of Project-I, Planning, fabrication and development of hardware / software and execution; relevant standards. (TRL-3: Technology Readiness Level 3 - Critical Function Proof-of-Concept)

1. Continuation of Project-I:
   - Review and refine the plan of work, objectives, and methodology established in the previous stage.
   - Address any feedback received during the Stage I evaluation.
2. Planning, Fabrication, and Development:
   - Detailed Planning: Develop a meticulous plan for the fabrication and development phase, including resource allocation, task breakdown, and revised timelines.
   - Hardware/ Software Development: If applicable, design, procure, and assemble hardware components. If applicable, write, debug, and test code modules, integrate software components, and develop user interfaces.
   - System Integration: Integrate hardware and software components (if both are present) to form a functional prototype or system.
3. Execution:
   - Implement the developed hardware/software according to the design specifications.
   - Conduct preliminary testing and debugging to identify and resolve issues.
   - Iteratively refine the design and implementation based on testing results.
4. Relevant Standards:
   - Identify and apply relevant industry standards, codes, and regulations pertinent to the project's domain (e.g., coding standards, communication protocols, safety standards, environmental regulations).
   - Ensure the developed solution meets specified performance and quality criteria.

The end semester evaluation shall be based on project work in power point presentation and a project report.