Department of Metallurgy and Materials Engineering

Honors

Title: New Material Process and Technology

Sem	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
III	HON-01	*<tbd>*	Modelling and Simulation	2	1	-	1	**3**	30	20	50	--	--
IV	HON-02	*<tbd>*	Waste Management	3	1	-	1	**4**	30	20	50	--	--
V	HON-03	*<tbd>*	Electrochemical Engineering	3	1	-	1	**4**	30	20	50	--	--
VI	HON-04	*<tbd>*	High Temperature Corrosion	3	1	-	1	**4**	30	20	50	--	--
VII	HON-05	*<tbd>*	Advances in Iron and Steel Making	2	1	-	1	**3**	30	20	50	--	--
			Total	**13**	**5**	**-**	**5**	**18**					

Title: Materials Engineering

Sem	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
III	HON-01	*<tbd>*	Modelling and Simulation	2	1	-	1	**3**	30	20	50	--	--
IV	HON-02	*<tbd>*	Fracture Mechanics	3	1	-	1	**4**	30	20	50	--	--
V	HON-03	*<tbd>*	Phase Transformation in Materials	3	1	-	1	**4**	30	20	50	--	--
VI	HON-04	*<tbd>*	Surface Coating Technology	3	1	-	1	**4**	30	20	50	--	--
VII	HON-05	*<tbd>*	Quantum Materials	2	1	-	1	**3**	30	20	50	--	--
			Total	**13**	**5**	**-**	**5**	**18**	**-**				

Interdisciplinary Minor

Title: Advanced Materials

Sem	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
III	IDP-01	*<tbd>*	Energy Materials	3	-	-	1	**3**	30	20	50	--	--
IV	IDP -02	*<tbd>*	Advanced Composites	4	-	-	1	**4**	30	20	50	--	--
V	IDP -03	*<tbd>*	Nanomaterials and Nanotechnology	4	-	-	1	**4**	30	20	50	--	--
VI	IDP -04	*<tbd>*	Advanced Materials Characterization	4	-	-	1	**4**	30	20	50	--	--
VII	IDP -05	*<tbd>*	Electronic and Magnetic Materials	3	-	-	1	**3**	30	20	50	--	--
			Total	**18**	**-**	**-**	**5**	**18**					

Detailed Syllabi - Honors: New Materials Process Technology

MODELLING AND SIMULATION						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	2-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Understand model roles, classifications, functions, and limitations.
2. Formulate mathematical models using conservation and constitutive laws.
3. Develop physical models, including phase-field methods.
4. Apply basic solution strategies and validate models.
5. Overview modern simulation and AI applications in materials.

Unit 1: Fundamentals of Materials Modelling and Mathematical Foundations **[6 Hrs]**

Introduction to modelling in Materials Science and Engineering, types, applications and limitations of models, modelling procedure and assumptions, conservative and constitutive equations.
Self-Study: Basic calculus, ordinary differential equations.

Unit 2: Physical Model Development **6 Hrs]**

Dynamic models and their applications, lumped parameter and distributed parameter models, development of mathematical models, development of rigorous and semi-rigorous physical models.
Self-Study: Partial differential equations, linear algebra and matrix operations.

Unit 3: Solution Methods and Model Validation **[6 Hrs]**

Solution strategies for basic governing equations, sensitivity analysis of model parameters, methods of data acquisition and analysis, techniques for model validation and performance evaluation.
Self-Study: Curve fitting techniques, introductory statistics for engineering applications.

Unit 4: Microstructure Modelling and Simulation Techniques **[6 Hrs]**

Phase-field methods for simulating solidification microstructures, fundamentals of simulation in materials engineering, molecular dynamics simulation, Monte Carlo simulation techniques.
Self-Study: Numerical methods for solving differential equations, probability concepts and random number generation.

Unit 5: Finite Element Analysis in Materials Engineering **[6 Hrs]**

Principles of finite element analysis, thermal analysis using finite element methods, stress analysis using finite element methods, applications of FEA in materials processing and manufacturing.
Self-Study: Fundamentals of discretization methods, mesh generation and element formulation

Unit 6: Artificial Intelligence and Industrial Applications **[6 Hrs]**

Introduction to fuzzy logic systems, fundamentals of neural networks and genetic algorithms, applications in phase diagram computation, applications in blast furnace modelling, steelmaking and materials processing.
Self-Study: Fundamentals of machine learning, optimization and evolutionary algorithms.

Textbooks:

[1]	S. Szekely, J.W. Evans and J.K. Brimakombe: The Mathematical and Physical Modelling of Primary Metals Processing Operations, Wiley.
[2]	D. Mazumdar and J.W. Evans: Modelling of Steel Making Processes, CRC.
[3]	N. Provatas and K. Elder: Phase-field Methods in Materials Science and Engineering, Wiley-VCH.
[4]	S. Rajasekaran, G.A.V. Pai: Neural networks, Fuzzy Logic and Genetic Algorithms

	Synthesis and Applications, Prentice-Hall of India.
Reference Books:	
[1]	R.J. Arsenault, J.R. Beeler, Jr. and D.M. Esterling (Eds.): Computer Simulation in Materials Science, ASM.
[2]	S. Yip: Modelling and Simulation Handbook
[3]	W.H. Press, S.A. Teukolsky, W.T. Vetterling and B.P. Flannery: Numerical Recipes, The art of scientific computing, 3rd ed., Cambridge.
[4]	I.M. Sibol: The Monte-Carlo method, Little Mathematics Library, Mir.

WASTE MANAGEMENT						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. To understand various types of wastes and their environmental impacts.
2. To introduce principles and technologies of waste collection, treatment, and disposal.
3. To explore regulatory, economic, and social aspects of waste management.
4. To promote sustainable and circular approaches to waste handling.

Unit 1: Fundamentals of Waste Management **[8 Hrs]**

Introduction to waste management, definition and classification of waste including solid, liquid, hazardous, biomedical and electronic waste, sources and characteristics of waste, history and evolution of waste management practices, impacts of improper waste disposal on human health and the environment, hierarchy of waste management and the concept of 5Rs (Refuse, Reduce, Reuse, Repurpose and Recycle).

Self-Study: *Municipal solid waste management systems, national and international waste management regulations.*

Unit 2: Electronic Waste Management **[8 Hrs]**

Classification and sources of electronic waste including household appliances, consumer electronics and EV batteries, composition of e-waste and hazardous substances such as lead, mercury and cadmium, environmental impacts of improper e-waste disposal, health risks associated with electronic waste exposure, collection, segregation and recycling approaches for e-waste.

Self-Study: Extended Producer Responsibility (EPR), emerging technologies for e-waste recycling.

Unit 3: Biomedical and Agro Waste Management **[8 Hrs]**

Classification and characteristics of biomedical waste, biomedical waste handling, segregation and disposal methods, types of agricultural waste including crop residues, animal waste and food processing waste, generation and environmental concerns of agro waste, sustainable utilization and management of agricultural residues.

Self-Study: Biomedical waste treatment technologies, bioenergy production from agricultural waste.

Unit 4: Plastic Waste Management **[8 Hrs]**

Sources and global generation of plastic waste, environmental and health impacts of plastic waste accumulation, plastic waste collection and recycling methods, alternatives to conventional plastics, development and applications of biodegradable and compostable plastics.

Self-Study: Life cycle assessment of plastics, recent advances in sustainable polymer materials.

Unit 5: Industrial and Hazardous Waste Management **[8 Hrs]**

Classification of industrial waste, sources and characteristics of hazardous waste, treatment and disposal methods for hazardous waste, design and operation of secure landfills and hazardous waste incinerators, waste minimization and cleaner production strategies in industries.

Self-Study: Industrial ecology and circular economy concepts, hazardous waste regulations and compliance.

Unit 6: Waste-to-Energy, Resource Recovery and Case Studies **[8 Hrs]**

Conversion of agricultural waste into value-added products such as animal feed and biomaterials, production of chemicals from agro waste, waste-to-energy technologies for plastic waste utilization, recovery of valuable metals from electronic waste, conversion of thermal power plant ash into value-added products, case studies on challenges and innovations in biomedical waste management.

Self-Study: Emerging waste-to-energy technologies, successful resource recovery and recycling case studies.	
Textbooks:	
[1]	Waste Management and Treatment Advances and Innovations by Rajpal A., CRC Press I Inc; 1st edition, 2025.
[2]	Electronic Waste Management: Policies, Processes, Technologies, and Impact by Sunil Kumar, Vineet Kumar, Wiley; 1st edition 2024.
[3]	Integrated solid waste management: engineering principles and management issues, by George Tchobanoglous, Hilary Theisen, S. A. Vigil, 1993.
Reference Books:	
[1]	Waste Management and Resource Recovery by Charles R. Rhyner, Leander J. Schwartz, Mary G. Kohrell, Robert B. Wenger, CRC Press Inc; 1st edition, 1995.

ELECTROCHEMICAL ENGINEERING						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Describe basic principles of Electrochemistry
2. Explore application of thermodynamics and kinetic principles for electrochemical cell.
3. Correlate energy and mass transport in the electrochemical cell.
4. Connect electrochemical behavior of cell with efficiency and its performance.
5. Evaluate selection criterion for electrolyte composition and electrode selection.
6. Develop processes for sustainable manufacturing of metals and its deposition.

Unit 1: Fundamentals of Electrochemical Engineering **[8 Hrs]**

Design of electrochemical processes, principles of energy and mass balance in electrochemical systems, electric currents in ionic conductors, thermodynamics of electrochemical systems, electrochemical reactions and cell performance analysis.

Self-Study: Fundamentals of oxidation-reduction reactions, electrochemical cell notation and conventions.

Unit 2: Transport Phenomena and Electrochemical Interfaces **[8 Hrs]**

Mass transfer in electrolytes, diffusion, migration and convection mechanisms, phase boundaries and interfaces between miscible electrolytes, electrode-electrolyte interactions, polarization of electrodes and its significance in electrochemical processes.

Self-Study: Fick's laws of diffusion, electrical double layer and interface phenomena.

Unit 3: Electrolytes and Industrial Electrolysis **[8 Hrs]**

Properties and applications of aqueous and nonaqueous electrolytes, principles of industrial electrolysis processes, design considerations for industrial electrolytic cells, efficiency and operational aspects of electrolysis systems.

Self-Study: Conductivity of electrolytes, industrial production of chlorine and aluminium through electrolysis.

Unit 4: Electrochemical Energy Storage and Conversion **[8 Hrs]**

Principles and operation of batteries, fuel cells and solid-state electrochemical devices, electrochemical energy conversion mechanisms, performance characteristics and applications of modern energy storage systems.

Self-Study: Lithium-ion battery technology, hydrogen economy and fuel cell applications.

Unit 5: Electrochemical Processing and Surface Engineering **[8 Hrs]**

Principles of electrowinning and electrodeposition, electrophoresis and its industrial applications, electroplating processes and coatings, electroless deposition processes, applications of electrochemical surface engineering in materials processing.

Self-Study: Corrosion protection by electrochemical coatings, nanostructured coatings through electrodeposition.

Unit 6: High-Temperature Electrolysis and Sustainable Electrochemical Processes **[8 Hrs]**

High-temperature electrolysis and types of electrolytes, applications in extraction and refining of rare earth metals, ferrous and non-ferrous metallurgical processes, green and sustainable electrochemical technologies, integration of renewable energy in electrochemical processes, environmental impact of electrolysis waste disposal, flue gases and their remedial measures.

Self-Study: Carbon-neutral metallurgical processes, waste management and emission control in electrochemical industries.

Textbooks:	
[1]	Bagotsky, Vladimir S., ed. Fundamentals of electrochemistry. John Wiley & Sons, 2005.
[2]	Krishnamurthy, N., and C. K. Gupta. "Rare earth metals and alloys by electrolytic methods." (2002): 477-507.
[3]	Shamsuddin, Mohammad, and TMS. Physical chemistry of metallurgical processes. Wiley, TMS, 2016.
Reference Books:	
[1]	Comninellis, Christos, and Guohua Chen, eds. Electrochemistry for the Environment. Vol. 2015. New York: Springer, 2010.

HIGH TEMPERATURE CORROSION						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Establish correlation between thermodynamic and high temperature corrosion.
2. Solve numerical.
3. Understand concepts and fundamentals in high temperature corrosion.
4. Knowledge of material selection for different

Unit 1: Fundamentals of High-Temperature Corrosion and Oxidation **[8 Hrs]**

Introduction to high-temperature corrosion and oxidation of metals and alloys, thermodynamics of gas-metal reactions, stability of oxides and sulphides, interpretation and applications of Ellingham diagrams, vapor species diagrams and isothermal stability diagrams.

Self-Study: Gibbs free energy and chemical equilibrium, thermodynamic principles of oxidation reactions.

Unit 2: Oxidation Kinetics and Mechanisms **[8 Hrs]**

Rate laws governing oxidation processes, kinetics and mechanisms of oxidation, Wagner's parabolic law of oxidation, derivation and limitations of Wagner's law, role of diffusion during oxidation, defect structures in oxides and their influence on oxidation behavior.

Self-Study: Fick's laws of diffusion, point defects and ionic transport in oxides.

Unit 3: Types of Oxidation and Scale Formation **[8 Hrs]**

General oxidation, selective oxidation and internal oxidation mechanisms, breakaway and catastrophic oxidation, multiple oxide scale formation, scale cracking and spallation phenomena, factors affecting oxidation resistance of engineering materials.

Self-Study: Pilling–Bedworth ratio and oxide scale adherence, microstructural effects on oxidation resistance.

Unit 4: High-Temperature Corrosion Phenomena **[8 Hrs]**

Forms of corrosion with special reference to external and internal oxidation, liquid metal embrittlement, hot corrosion mechanisms, corrosion in mixed gaseous environments, degradation of materials under aggressive high-temperature service conditions.

Self-Study: Sulfidation and carburization processes, corrosion failures in industrial components.

Unit 5: Corrosion Prevention and Protective Technologies **[8 Hrs]**

Prevention of high-temperature corrosion through material selection and design, alteration of service environments, corrosion inhibition techniques, metallic and ceramic paints, protective coatings and surface treatments for high-temperature applications.

Self-Study: Thermal barrier coatings, advanced surface engineering techniques for corrosion protection.

Unit 6: High-Temperature Materials and Industrial Case Studies **[8 Hrs]**

High-temperature materials including superalloys, intermetallic compounds and advanced ceramics, material performance in extreme environments, case studies of high-temperature oxidation and corrosion in power plants, gas turbines, petrochemical plants and related industrial systems.

Self-Study: Nickel-based superalloys for turbine applications, emerging ultra-high-temperature ceramic materials.

Textbooks:

[1]	High Temperature Corrosion of Materials-by Kofstadt

[2]	High Temperature Oxidation of Metals and Alloys –by N.Birks and Meir
[3]	Fundamentals of Corrosion- Scully
[4]	Riedel H. – Fracture of High Temp., Springer-Verlag, Berlin,1987.
Reference Books:	
[1]	.M.West-Basic Corrosion & Oxidation, 2nd Edition, Ellis Harwood Publication, 1986.
[2]	ASM Metals H.B., Vol. 13, ASM international, Metals park, Ohio, 1986.

ADVANCES IN IRON AND STEEL MAKING						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	2-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Explain metallurgical benefits of ingot and continuous cast products.
2. Understand raw materials quality and sequence of refining for making clean steel.
3. Relate the cost of the steel by careful selection of the raw materials and other necessary ingredients required for steel manufacturing.
4. Develop ways for energy conservation and environmental pollution.
5. Design alloy chemistry for manufacturing /procurement of desired composition of the steel as per the specification.

Unit 1: Raw Materials and Fundamentals of Steelmaking **[6 Hrs]**

Raw materials used in steelmaking including iron-bearing materials, refractories, steel scrap and fluxes, properties and selection criteria of steelmaking raw materials, sponge iron production and its role in modern steelmaking processes.

Self-Study: Iron ore beneficiation techniques, characterization of refractories used in steel plants.

Unit 2: Electric Furnace Steelmaking **[6 Hrs]**

Principles of electric furnace steelmaking, construction and operation of electric arc furnaces, transformer rating and electrical requirements, primary and secondary electrical circuits, power factor considerations, thermal efficiency and energy utilization in electric furnace operations.

Self-Study: Energy conservation in electric arc furnaces, electrical fundamentals of industrial furnaces.

Unit 3: Ladle Metallurgy and Secondary Steel Refining **[6 Hrs]**

Construction and operation of ladle refining furnaces (LRF), principles of steel refining technology, removal of dissolved gases from molten steel, deoxidation practices and control of non-metallic inclusions, influence of slag composition on steel quality, secondary refining processes including AOD, VOD and VD.

Self-Study: Calcium treatment and inclusion modification, vacuum metallurgy principles and applications.

Unit 4: Continuous Casting Technology **[6 Hrs]**

Construction and operation of continuous casting machines, production of blooms, billets, slabs and thin strips through continuous casting, primary and secondary cooling systems, process parameters affecting casting quality, defects and quality control in continuous casting operations.

Self-Study: Mold powder functions in continuous casting, breakout prevention and monitoring systems.

Unit 5: Ingot Casting and Electromagnetic Stirring **[6 Hrs]**

Principles of ingot casting, types of casting moulds and their applications, defects in ingot and continuously cast products, principles of electromagnetic stirring (EMS) for quality improvement, types of EMS, selection criteria, advantages and limitations of electromagnetic stirring techniques.

Self-Study: Solidification behavior in steel ingots, macro segregation and its control in cast products.

Unit 6: Environmental Aspects of Steelmaking **[6 Hrs]**

Sources and mechanisms of dust generation in steelmaking furnaces, environmental impacts of particulate emissions from steel plants, dust collection and control systems, waste management practices in steelmaking industries, sustainable and environmentally responsible steel production

technologies. *Self-Study: Air pollution control equipment in steel plants, carbon footprint reduction strategies in steelmaking.*	
Textbooks:	
[1]	Irving, William R. Continuous casting of steel. CRC Press, 2024.
[2]	Steel Making –V. Kudrin, Mir. Publisher, 1998
[3]	Introduction to Modern Steel Making- Dr. R.H. Tupkari, Khanna Publishers, 2012
[4]	Electrometallurgy-I - By Edneral, 1962
[5]	Moore, John J. "Continuous Casting " Iron and Steel Institute, 1984
Reference Books:	
[1]	Ahindra Ghosh, Amit Chatterjee Iron and Steel making: Theory and practice, 2ndEdition, PHI learning Pvt. Ltd, New Delhi, 2011
[2]	Madias, Jorge. "Electric arc furnace." Ironmaking and Steelmaking Processes: Greenhouse Emissions, Control, and Reduction, 2016

Detailed Syllabi - Honors: Materials Engineering

MODELLING AND SIMULATION

Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	2-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

6. Understand model roles, classifications, functions, and limitations.
7. Formulate mathematical models using conservation and constitutive laws.
8. Develop physical models, including phase-field methods.
9. Apply basic solution strategies and validate models.
10. Overview modern simulation and AI applications in materials.

Unit 1: Fundamentals of Materials Modelling and Mathematical Foundations **[6 Hrs]**

Introduction to modelling in Materials Science and Engineering, types, applications and limitations of models, modelling procedure and assumptions, conservative and constitutive equations.
Self-Study: Basic calculus, ordinary differential equations.

Unit 2: Physical Model Development **[6 Hrs]**

Dynamic models and their applications, lumped parameter and distributed parameter models, development of mathematical models, development of rigorous and semi-rigorous physical models.
Self-Study: Partial differential equations, linear algebra and matrix operations.

Unit 3: Solution Methods and Model Validation **[6 Hrs]**

Solution strategies for basic governing equations, sensitivity analysis of model parameters, methods of data acquisition and analysis, techniques for model validation and performance evaluation.
Self-Study: Curve fitting techniques, introductory statistics for engineering applications.

Unit 4: Microstructure Modelling and Simulation Techniques **[6 Hrs]**

Phase-field methods for simulating solidification microstructures, fundamentals of simulation in materials engineering, molecular dynamics simulation, Monte Carlo simulation techniques.
Self-Study: Numerical methods for solving differential equations, probability concepts and random number generation.

Unit 5: Finite Element Analysis in Materials Engineering **[6 Hrs]**

Principles of finite element analysis, thermal analysis using finite element methods, stress analysis using finite element methods, applications of FEA in materials processing and manufacturing.
Self-Study: Fundamentals of discretization methods, mesh generation and element formulation

Unit 6: Artificial Intelligence and Industrial Applications **[6 Hrs]**

Introduction to fuzzy logic systems, fundamentals of neural networks and genetic algorithms, applications in phase diagram computation, applications in blast furnace modelling, steelmaking and materials processing.
Self-Study: Fundamentals of machine learning, optimization and evolutionary algorithms.

Textbooks:

[1]	S. Szekely, J.W. Evans and J.K. Brimakombe: The Mathematical and Physical Modelling of Primary Metals Processing Operations, Wiley.
[2]	D. Mazumdar and J.W. Evans: Modelling of Steel Making Processes, CRC.
[3]	N. Provatas and K. Elder: Phase-field Methods in Materials Science and Engineering, Wiley-VCH.
[4]	S. Rajasekaran, G.A.V. Pai: Neural networks, Fuzzy Logic and Genetic Algorithms

	Synthesis and Applications, Prentice-Hall of India.
Reference Books:	
[1]	R.J. Arsenault, J.R. Beeler, Jr. and D.M. Esterling (Eds.): Computer Simulation in Materials Science, ASM.
[2]	S. Yip: Modelling and Simulation Handbook
[3]	W.H. Press, S.A. Teukolsky, W.T. Vetterling and B.P. Flannery: Numerical Recipes, The art of scientific computing, 3rd ed., Cambridge.
[4]	I.M. Sibol: The Monte-Carlo method, Little Mathematics Library, Mir.

FRACTURE MECHANICS						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Understand fundamental concepts in fracture mechanics, elasticity, and plasticity theory.
2. Analyze stress and strain states using stress and strain tensors and solve problems using Mohr's circle.
3. Quantify fracture toughness using methods like stress intensity factor (K_IC), J-integral, R-curve, and CTOD.
4. Design materials for damage-tolerant applications based on fracture mechanics principles.

Unit 1: Fundamentals of Fracture Mechanics and Solid Mechanics **[8 Hrs]**

Introduction to fracture mechanics, fundamentals of elasticity and plasticity theory, stress and strain concepts in engineering materials, fundamental equations governing elasticity and plasticity, significance of fracture mechanics in engineering design and failure analysis.
Self-Study: Hooke's law and elastic constants, yield criteria for ductile materials.

Unit 2: Stress and Strain Analysis **[8 Hrs]**

Stress and strain tensors, transformation of stresses and strains, Mohr's circle for stress analysis, principal stresses and strains, applications of tensor analysis in material deformation and failure.
Self-Study: Tensor notation and matrix representation, stress transformation in two-dimensional systems.

Unit 3: Fracture Behaviour of Materials **[8 Hrs]**

Mechanisms of brittle and ductile fracture, crack initiation and propagation, strain energy release rate and its significance, Griffith theory of brittle fracture, factors affecting fracture behaviour of engineering materials.
Self-Study: Fractography of brittle and ductile failures, microstructural influences on fracture behavior.

Unit 4: Linear Elastic Fracture Mechanics **[8 Hrs]**

Concepts of linear elastic fracture mechanics (LEFM), stress intensity factors for different modes of crack loading, Mode I, Mode II and Mode III fracture, relationship between strain energy release rate and stress intensity factor, applications of LEFM in structural integrity assessment.
Self-Study: Crack tip stress fields, fracture toughness testing under linear elastic conditions.

Unit 5: Elastic-Plastic Fracture Mechanics **[8 Hrs]**

Classification and principles of elastic-plastic fracture mechanics (EPFM), limitations of linear elastic fracture mechanics, quantification of fracture toughness using J-integral, R-curve and crack tip opening displacement (CTOD), fracture resistance behaviour of ductile materials.
Self-Study: Stable and unstable crack growth, ASTM standards for fracture toughness evaluation.

Unit 6: Damage Tolerant Design and Engineering Applications **[8 Hrs]**

Principles of damage tolerant design, fracture mechanics approach to safe life and fail-safe design, assessment of structural reliability using fracture mechanics concepts, case studies on the design and selection of materials for damage tolerant applications in aerospace, power generation and structural engineering.
Self-Study: Fatigue crack growth analysis, fracture mechanics applications in aerospace and pressure vessel design.

Textbooks:	
[1]	R. W. Hertzberg, R. P. Vinci, J. L. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, 5th Edition, Wiley, 2012, ISBN-10: 0470527803.
[2]	G. E. Dieter, Mechanical Metallurgy, 3rd Edition, McGrawHill, 2017, ISBN: 0071004068.
Reference Books:	
[1]	T. L. Anderson, Fracture Mechanics: Fundamentals and Applications, 4th Edition, CRC Press, 2017, ISBN10: 1498728138.
[2]	R. J. Sanford, Principles of Fracture Mechanics, 1st Edition, Pearson, 2002, ISBN-10: 0130929921.

PHASE TRANSFORMATIONS IN MATERIALS						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Utilize the knowledge of phase transformation in industries & research organizations.
2. Analyze, interpret and present observations on heat treatment.
3. Function in engineering units and science laboratory teams, as well as on multidisciplinary projects.

Unit 1: Solution Thermodynamics and Phase Diagrams [8 Hrs]

Basics of solution thermodynamics, concept of excess free energy, regular solution model, binary phase diagrams and their interpretation, ternary phase diagrams and interpretation of tie lines in ternary isothermal sections, thermodynamic basis of phase stability and equilibrium.

Self-Study: Gibbs phase rule and phase equilibria, thermodynamic activities and activity coefficients.

Unit 2: Diffusion and Nucleation in Solids [8 Hrs]

Kinetics of phase transformations, classification of phase transformations, mechanisms of diffusion in solids, steady-state and non-steady-state diffusion, factors affecting diffusion rates, Kirkendall effect, energy aspects of homogeneous and heterogeneous nucleation, nucleation processes in solid-state transformations.

Self-Study: Fick's laws of diffusion, vacancy and interstitial diffusion mechanisms.

Unit 3: Transformation Kinetics in Steels [8 Hrs]

Fraction transformed at constant rates of nucleation and growth, austenite-to-pearlite transformation and influence of temperature on pearlite formation, austenite-to-bainite transformation and associated microstructural evolution, transformation kinetics and time-temperature-transformation concepts.

Self-Study: TTT and CCT diagrams, microstructural characterization of pearlite and bainite.

Unit 4: Martensitic and Order–Disorder Transformations [8 Hrs]

Martensitic transformation and its crystallographic aspects, mechanisms of atomic movement during martensitic transformation, comparison between twinning and martensitic transformation, effects of grain size, plastic deformation and arrested cooling on transformation kinetics, order-disorder transformations, common structures in ordered alloys, variation of degree of order with temperature, determination of degree of ordering, influence of ordering on material properties and engineering applications.

Self-Study: Shape memory alloys and martensitic transformations, superlattice structures in ordered alloys.

Unit 5: Precipitation Hardening and Spinodal Decomposition [8 Hrs]

Principles of precipitation hardening, structural changes during age hardening treatments, mechanisms and kinetics of precipitation reactions, effects of retrogression and re-aging treatments, occurrence of double hardness peaks, spinodal decomposition and its role in strengthening mechanisms.

Self-Study: Age hardening in aluminium alloys, coherent and incoherent precipitates.

Unit 6: Recovery, Recrystallization, Grain Growth and Ceramic Transformations [8 Hrs] Recovery, recrystallization and grain growth processes, property changes during annealing treatments, driving forces and nucleation-growth aspects of recrystallization, annealing twins and texture development in cold-worked and annealed alloys, polygonization and subgrain formation, phase transformations in ceramics and their influence on properties and performance. *Self-Study: Grain boundary engineering, transformation toughening in ceramics.*	
Textbooks:	
[1]	Solid State Phase Transformations by V. Raghavan, Prentice-Hall of India (P) Ltd., N. Delhi, 1987.
[2]	Phase Transformation in Metals and Alloys by David A. Porter, Kenneth E. Easterling, and Mohamed Y. Sherif, CRC Press, 3rd Ed. (Indian reprint), 2009.
[3]	Materials Science and Engineering, An introduction, by William D. Callisters, Jr., 7th Edition, John Wiley & Sons, Inc, 2011.
Reference Books:	
[1]	Modern Physical Metallurgy and Materials Enginering by R. E. Smallman and R.J. Bishop, 6th Edition, Butterworth Heinemann, 1999.
[2]	Recovery Recrystallization & Grain Growth in Metals – P. Cotterill& P. R. Mould- Surrey University Press. Physical Metallurgy – Cahn, Haasen, North Holland Physics Publication.

SURFACE COATING TECHNOLOGY						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Understand the role of surface engineering in enhancing product performance.
2. Explain surface-dependent properties like mechanical, thermal, and optical behavior.
3. Describe major surface coating methods such as CVD, PVD, and electroplating.
4. Analyze how process parameters influence coating quality and performance.
5. Select appropriate coating methods based on application requirements.
6. Evaluate coating properties using standard testing and characterization techniques.

Unit 1: Fundamentals of Surface Engineering [8 Hrs]

Significance of surface engineered materials in modern engineering applications, importance of surface properties in determining component performance, surface-dependent engineering properties including mechanical, chemical, thermal, electrical, electronic and optical properties, role of surface engineering in enhancing service life and functionality of engineering components.

Self-Study: Surface energy and wettability concepts, industrial applications of surface engineering.

Unit 2: Surface Modification Technologies [8 Hrs]

Role of surface coating and surface modification technologies in achieving desired surface characteristics, classification of surface modification processes, mechanically modified surfaces and associated techniques, thermally modified surfaces and their engineering applications, scope and limitations of various surface modification methods.

Self-Study: Surface hardening techniques, laser and plasma-based surface modification processes.

Unit 3: Surface Coating Technologies [8 Hrs]

Fundamentals of surface coating processes, chemical vapour deposition (CVD), physical vapour deposition (PVD), electrodeposition and electroless deposition processes, thermal spray coating techniques, coating deposition by wetting and related methods, applications of different coating technologies in engineering industries.

Self-Study: Atomic layer deposition and advanced thin film technologies, industrial applications of thermal spray coatings.

Unit 4: Coating Process Parameters and Selection Criteria [8 Hrs]

Process parameters influencing coating deposition and coating quality, factors controlling coating yield and efficiency, influence of processing variables on coating microstructure and properties, criteria for selection of suitable surface coating technologies, economic and performance considerations in coating process selection.

Self-Study: Process optimization in coating technologies, defect formation and control in coatings.

Unit 5: Coating Systems and Substrate Engineering [8 Hrs]

Product-oriented surface coating technologies, design and components of coating systems, functions of various layers and elements in coating systems, substrate technology and its significance in achieving high-performance coatings, coating-substrate interactions and adhesion mechanisms.

Self-Study: Interfacial phenomena in coating systems, bond coat and multilayer coating concepts.

Unit 6: Characterization and Performance Evaluation of Coatings [8 Hrs]	
Physical and mechanical characterization of coatings, microstructural analysis of coated surfaces, measurement of coating thickness, hardness and adhesion strength, methods for evaluating coating performance under service conditions, testing of wear, corrosion and thermal resistance of coatings, failure analysis of coated components. *Self-Study: Advanced surface characterization techniques, non-destructive evaluation of coatings.*	
Textbooks:	
[1]	J. R. Davis, Surface Engineering for Corrosion and Wear Resistance, 3rd ed. Materials Park, OH: ASM International, 2017.
[2]	P. M. Martin, Introduction to Surface Engineering and Functionally Engineered Materials. Hoboken, NJ: Wiley, 2009.
[3]	K. G. Budinski and M. K. Budinski, Surface Engineering, 2nd ed. Upper Saddle River, NJ: Prentice Hall, 2010.
[4]	J. C. Riviere and S. Myhra, Eds., Handbook of Surface and Interface Analysis: Methods for Problem-Solving, 2nd ed. Boca Raton, FL: CRC Press, 2009.
[5]	E. Lugscheider, Ed., Surface Engineering of Materials: Principles, Equipment, Technologies. Boca Raton, FL: CRC Press, 1998.
Reference Books:	
[1]	S. Bose, Surface Engineering: Science and Technology. Boca Raton, FL: CRC Press, 2017.
[2]	L. Pawlowski, The Science and Engineering of Thermal Spray Coatings, 2nd ed. Hoboken, NJ: Wiley, 2008.
[3]	Y. Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, 2nd ed. Hoboken, NJ: Wiley, 2013.
[4]	R. Chattopadhyay, Advanced Surface Coating Techniques for Modern Industrial Applications. Berlin: Springer, 2011.
[5]	L. S. Newman, Electroplating and Electroforming: A Guide for the Craftsman. Bradley, IL: Lindsay Publications, 2005

QUANTUM MATERIALS						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	2-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Demonstrate knowledge of quantum mechanics in relation to crystal materials and understanding of wave mechanics in one and three dimensions.
2. Understand the purely quantum mechanical idea of spin, and how to represent and visualize it.
3. Understand the basic properties of quantum magnetism and some initial knowledge in exotic quantum materials, such as superconducting materials.

Unit 1: Foundations of Quantum Mechanics **[6 Hrs]**

The limitations of classical physics and the emergence of quantum theory, foundational experiments including the photoelectric effect and Compton scattering, wave-particle duality of matter and radiation, development of quantum concepts and their significance in understanding modern materials.

Self-Study: Blackbody radiation and Planck's hypothesis, de Broglie wavelength and matter waves.

Unit 2: Quantum Mechanical Formalism **[6 Hrs]**

The Schrödinger equation in one and three dimensions, wave functions and their physical interpretation, eigenvalues and eigenfunctions, Heisenberg's uncertainty principle, quantum tunneling phenomena, potential wells and particle confinement in quantum systems.

Self-Study: Operators in quantum mechanics, particle in a box and harmonic oscillator models.

Unit 3: Quantum Theory of Solids and Electronic Structure **[6 Hrs]**

The free electron model of solids, crystal lattice periodicity and Bloch's theorem, reciprocal lattices and Brillouin zones, formation of energy bands in solids, density of states and k-space representation, quantum description of conductors, semiconductors and insulators.

Self-Study: Nearly free electron model, effective mass concept in semiconductors.

Unit 4: Quantum Statistics and Lattice Dynamics **[6 Hrs]**

Quantum statistical distributions including Fermi-Dirac and Bose-Einstein statistics, occupancy of energy states in solids, density of states calculations, quantum mechanical treatment of lattice vibrations, phonons and their role in thermal, electrical and optical properties of materials.

Self-Study: Debye and Einstein models of specific heat, thermal conductivity mechanisms in solids

Unit 5: Quantum Magnetism and Superconductivity **[6 Hrs]**

Quantum theory of magnetism including diamagnetism, paramagnetism and ferromagnetism, exchange interactions and spin systems, magnetic ordering phenomena, introduction to superconductivity, superconducting materials and the Josephson effect, applications of superconducting technologies.

Self-Study: Meissner effect and critical parameters of superconductors, antiferromagnetism and ferrimagnetism.

Unit 6: Advanced Quantum Materials and Emerging Topics **[6 Hrs]**

Quantum wells and low-dimensional systems, band-gap engineering and semiconductor heterostructures, topological materials and their unique electronic properties, quantum entanglement in condensed matter systems, emerging quantum materials and their applications in next-generation technologies.

Self-Study: Quantum dots and nanostructures, quantum computing materials and spintronics.

Textbooks:	
[1]	Eisberg, Robert M., and Robert Resnick. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles. Wiley, 1985. ISBN: 9780471873730.
[2]	Liboff, Richard L. Introductory Quantum Mechanics. Addison Wesley, 2002. ISBN: 9780805387148.
[3]	Gasiorowicz, Stephen. Quantum Physics. John Wiley & Sons, 2003. ISBN: 9780471429456.
[4]	Shankar, Ramamurti. Principles of Quantum Mechanics. Springer, 2008. ISBN: 9780306447907.
Reference Books:	
[1]	Dirac, Paul Adrien Maurice. The Principles of Quantum Mechanics. Clarendon Press, 2011. ISBN: 9780198520115.
[2]	Griffiths, David J. Introduction to Quantum Mechanics. Upper Saddle River, Pearson Prentice Hall, 2005. ISBN: 9780131118928.
[3]	Feynman, Richard P., Robert B. Leighton, and Matthew L. Sands. The Feynman Lectures on Physics. Addison Wesley, 1989. ISBN: 9780201500646.

Detailed Syllabi - Interdisciplinary Minor: Advanced Materials

ENERGY MATERIALS						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

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

Unit 1: Nuclear Materials: **[6 Hrs]**

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.

Unit 2: Hydrogen: Hydrogen Storage alloys **[6 Hrs]**

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.

Unit 3: Rare earth metals **[6 Hrs]**

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 reduction of carbon footprint.

Unit 4: Rare earth metals (La, Nd, Ce, Pr and others) **[6 Hrs]**

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.

Unit 5: Solar Energy materials **[6 Hrs]**

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.

Unit 6: Metal/nonmetals **[6 Hrs]**

Metal/nonmetals: 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.

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.

ADVANCED COMPOSITE MATERIALS						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	4-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Classify composite materials by matrix, reinforcement, and functionality.
2. Analyze processing routes and microstructure–property relationships.
3. Apply micromechanics, failure theories, and simulation tools to predict behavior.
4. Design and execute a mini-project integrating multidisciplinary composite concepts.
5. Evaluate sustainability, cost, and ethical considerations in composite selection.
6. Communicate technical findings effectively through reports and presentations.

Unit 1: Fundamentals & Processing **[8 Hrs]**

The basic definitions and classifications of composite materials—including polymer, metal, ceramic, carbon–carbon, and cement-matrix systems. Microstructure of reinforcements (fibers, whiskers, particulates) and Processing routes such as hand lay-up, resin transfer molding (RTM), vacuum-assisted RTM, stir casting, chemical vapor deposition (CVD), and sintering.

Self-study: Recent industrial case studies illustrating how different composite families (PMC, MMC, CMC) are selected for high-performance applications.

Unit 2: Reinforcements & Elastic Behavior **[8 Hrs]**

High-performance glass, carbon, aramid, and natural fibers, as well as carbon-based nanofillers like carbon nanotubes and graphene. Fiber production and microstructure, dispersion and functionalization of nanofillers, and elastic-modulus prediction via rule-of-mixtures and related micromechanical models.

Self-study: Comparison of natural vs. synthetic fiber composites in terms of sustainability and mechanical performance. Survey of popular micromechanics-based software tools (e.g., MATLAB toolboxes, simple ANSYS modules) for predicting elastic moduli.

Unit 3 Advanced Mechanical Behavior & Durability **[8 Hrs]**

Composite strength, ductility, damage mechanisms, and vibration-damping phenomena. Corrosion, thermal and mechanical fatigue, UV and environmental degradation.

Self-study: Review of modern nondestructive evaluation (NDE) standards and practices for composites (ASTM/ISO). Exploration of how environmental factors (humidity, temperature) influence long-term composite performance.

Unit 4: Structural Composites, Joining & Repair **[8 Hrs]**

Applications of lightweight PMC, MMC, and CMC systems in aerospace, automotive, and civil infrastructure. Joining techniques—welding, brazing, adhesive bonding, and mechanical fastening with repair strategies, including patch-repair methods and emerging self-healing materials

Self-study: Case studies on composite repair in critical industries (aerospace engine components, wind turbine blades). Overview of hybrid joining methods (adhesive + mechanical fastening) and why they're chosen over single techniques.

Unit 5: Interface Engineering **[8 Hrs]**

Interface modification approaches—chemical coatings, surface treatments, and microstructure control. Organic–inorganic hybrid architectures and nanoscale interfacial designs are examined, design exercises on selecting appropriate interface treatments

Self-study: Survey of surface-treatment methods (chemical, plasma, nano-coatings) used to optimize fiber–matrix bonding. Examples of bio-inspired interfacial designs and what they teach us

about composite toughness and durability.	
Unit 6: Functional Properties	**[8 Hrs]**
Electrical properties: conduction mechanisms, resistivity models, electromagnetic-shielding effectiveness, and piezoresistive sensing. Thermal properties: expansion, specific heat, phase-change materials, thermal conductivity, interface conductance, and measurement techniques such as laser-flash analysis *Self-study: Industry examples of multifunctional composites (e.g., EMI-shielding panels in electronics enclosures). Comparison of common thermal- and electrical-property measurement techniques and their practical setups.*	
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.

NANOMATERIALS AND NANOTECHNOLOGY						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	4-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. know the length scale and surface area to volume ratio of materials with decreasing size of particles. And to compare the properties of nanomaterials to that of bulk.
2. know the effect of particles or grains size on mechanical, thermal, optical and electrical properties of nanomaterials and synthesis the nanomaterials by top-down and bottom-up approaches.
3. understand the theoretical concepts of synthesis, purification, and applications of carbon nanotubes.
4. apply the knowledge to prepare and characterize nanomaterials and their nanocomposites and know characterization of nanomaterials using x-ray diffraction, laser particle size analyzer, transmission electron microscope (TEM) etc.
5. understand the theoretical concepts of about the applications of nanomaterials in structural, electronics, optical, magnetic, and bio-medical fields, nanocomposites etc.

Unit 1: Introduction to nanomaterials and nanotechnology	**[8 Hrs]**

Length scales, surface rea/volume ratio of micron to nanoscale materials, Importance of Nanoscale and Technology, Top down and bottom-up approaches, Classification of nanomaterials, effect of particle size on thermal properties, electrical properties, phase transformation, mechanical properties, magnetic properties, optical properties, wear resistance and chemical sensitivity. Examples

Unit 2: Synthesis of Nanomaterials	**[8 Hrs]**

Top-down approaches-lithography, mechanical alloying, severe plastic deformation, Bottom-up approaches-physical vapour deposition, chemical vapour deposition, molecular beam epitaxy, colloidal or wet chemical route, green chemistry route, sol-gel method, atomic layer deposition, combustion method of inspiration from the Nature and ancient history

Unit 3 Synthesis of Nanomaterials	**[8 Hrs]**

Top-down approaches-lithography, mechanical alloying, severe plastic deformation, Bottom-up approaches-physical vapour deposition, chemical vapour deposition, molecular beam epitaxy, colloidal or wet chemical route, green chemistry route, sol-gel method, atomic layer deposition, combustion method.

Unit 4: Characterization of Nanomaterials	**[8 Hrs]**

Basic principle and applications of X-ray diffraction (XRD), Optical spectroscopy, Surface area analysis (BET method), Light scattering method, Scanning electron microscope (SEM), Transmission Electron Microscope (TEM), Scanning probe microscopy- Atomic force microscope (AFM) and scanning tunneling microscope (STM), X-ray photoelectron spectroscopy, Thermal analyser.

Unit 5: Applications of nanomaterials	**[8 Hrs]**

Nanofluids, hydrogen storage, solar energy, antibacterial coating, self-cleaning coating, nanotextiles, biomedical field, water treatment, automotive sector, catalysts, nanopore filters, nanodiamond.

Unit 6: Challenges, Toxicity and Recent Advances in Nanotechnology	**[8 Hrs]**

Challenges of nanomaterials, Risks and toxicity from metallic and oxide nanoparticles, Recent advances in nanoscience and nanotechnology	
Textbooks:	
[1]	Rajendra Kumar Goyal," Nanomaterials and nanocomposites: Synthesis, Properties, Characterization Techniques and Applications" CRC Press, 2017, ISBN: 978-14987616662017.
[2]	B.S. Murty, P. Shankar, Baldev Raj, B B Rath, James Murday, "Textbook of Nanoscience and Nanotechnology", 2013, University Press (I) Pvt. Ltd. (e-ISBN: 978-3-642-28030-6).
[3]	Gábor Louis Hornyak, Harry F. Tibbals, Joydeep Dutta," Introduction to nanoscience and nanotechnology", 2009, CRC Press (ISBN: 1420047795, 9781420047790).
[4]	Charles P. Poole, Jr. and Frank J. Owens, "Introduction to Nanotechnology", 2003,
Reference Books:	
[1]	Dieter Vollath, "Nanomaterials: An introduction to synthesis, properties and applications", 2nd Edition, Aug 2013, Wiley-CVH (ISBN: 978-3-527-33379-0)
[2]	Kenneth J. Klabunde, "Nanoscale Materials in Chemistry", Aug 2003, Wiley- Interscience (ISBN: 9780471460787)
[3]	Hari Singh Nalwa, "Encyclopedia of Nanoscience and Nanotechnology", Volume 1, 2003, American Scientific Publishers (ISBN: 1588830012).
[4]	Bharat Bhusan, "Handbook of Nanotechnology",3rd Revision, 2010, Springer-Verlag Publication media (ISBN: 978-3-642-02524-2)
[5]	Guozhong Cao and Ying Wang, "Nanostructures and Nanomaterials: Synthesis, Properties and Applications", 2nd Edition, 2011, World Scientific (ISBN: 978-981- 4322-50-8)

ADVANCED MATERIALS CHARACTERISATION						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	4-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: 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.

Unit 1: Optical microscopy	**[8 Hrs]**

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

Unit 2: General concepts of electron microscopy	**[8 Hrs]**

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

Unit 3 Transmission electron microscope	**[8 Hrs]**

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

Unit 4: Scanning electron microscope	**[8 Hrs]**

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.

Unit 5: X-ray Diffraction	**[8 Hrs]**

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.	
Unit 6: Other characterization techniques	**[8 Hrs]**
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*	

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.

Electronics and Magnetic Materials						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --	ESE: --	--

Course Outcomes: Students will be able to:

1. Identify and explain the basic principles of various electronic and magnetic materials.
2. Apply various laws and relations to evaluate the suitability of various electronic and magnetic materials for a particular application.
3. Analyze the effect of process parameters on the structure - property relationship of electrical engineering materials.
4. Engineer the synthesis-structure property relationship for the electronic materials according to recent commercial applications.

Unit 1: Conduction Mechanisms in Metals and Non-Metals **[6 Hrs]**

Electrical and Thermal Conduction In Solid metal and conduction by electrons, Resistivity and its Temperature dependence, Thermal Conductivity, Thermal Resistance Temperature coefficient of Resistivity, Impurity Effect, Resistivity Mixture Rule, Skin Effect. Electrical Conductivity of Non - Metals: Ionic Crystals and Glasses, Semiconductors, Solar Radiation Fundamentals

Self-study: Crystal Structure and Electrical Properties, Atomic Bonding and Material Properties, Energy Resources and Solar Energy Basics

Unit 2: Semiconductor Materials and Microelectronic Devices **[6 Hrs]**

Semiconductors, Extrinsic, Intrinsic, Recombination and Generation in Semiconductors, Semiconductor Devices, Compound Semiconductor, Metal Semiconductor contacts, Microelectronic Devices Such as LED, CMOS, MOSFETS, BPT etc, Manufacturing Methods and Applications, Si wafer Manufacturing, Solar Cell Device and Quantum Efficiency Calculations

Self-study: Evolution of Semiconductor Technology, Moore's Law and Integrated Circuits, Electronic Materials in Everyday Devices

Unit 3 Magnetic Properties in materials **[6 Hrs]**

Magnetic Field and Quantities, Classification of Magnetic Materials, Ferromagnetism Origin, Exchange Interaction, Saturation Magnetization, Curie Temperature, Ferromagnetic Domains, Magnetostriction, Demagnetization

Self-study: Earth's Magnetism, Historical Development of Magnetic Materials, Magnetic Materials in Daily Life

Unit 4: Magnetic Alloys **[6 Hrs]**

Soft and Hard Magnetic materials, Ferrites, Magnetic Recording Materials, Magnetic Resonance Imaging. Superconductivity: Zero Resistance, Meissner Effect, Type I and II Superconductors, BCS Theory, Magnetoelectric materials, Multiferroicity

Self-study: Discovery and History of Superconductivity, Cryogenic Materials and Cooling Systems, Applications of MRI and NMR

Unit 5: Optical Properties of Materials **[6 Hrs]**

Light and Electromagnetic Spectrum, Refraction, Absorption, Transmission and Reflection of Light, Luminescence, Laser, Optical Spectral bands, Basic optical laws and definitions, Optical fibers Modes and configurations, Fiber materials and fabrication, Optical Anisotropy, Electrooptic Effect, Electro-optic Ceramics, Antireflection Coating on Solar Cell.

Self-study: Nature and Sources of Light, Electromagnetic Spectrum and Its Applications, Optical Materials in Daily Life

Unit 6: Dielectric Materials and Insulation		[6 Hrs]
Polarization, Relative Permitivity, Polarization Mechanisms, Dielectric Constant, Dielectric Loss, Capacitors and Insulators, Piezoelectric, Ferro Electric and Pyroelectric Materials, Supercapacitors. *Self-study: Electrical Safety and Insulation Systems, Energy Storage Technologies, Smart and Functional Materials*		
Textbooks:		
[1]	William F. Smith , Javed Hashemi, Ravi Prakash, " Foundation of Materials Science and Engineering", TATA Mc Graw-Hill International Edition,4th Edition, 2008.	
[2]	N. Braithwaite and G. Weaver," Materials in Action Series -Electronic Materials", Butterworths Publication.	
[3]	S. O. Kasap," Principles of Electronic Materials and Devices", Tata Mc Graw-Hill Publication, 2nd Edition, 2002.	
[4]	Robert Pierret, "Advanced Semiconductor Fundamentals", Vol.6 (Modular Series on Solid State Devices, Vol 6), 1987, Pearson Publication.	
[5]	S. M. Sze, Physics of Semiconductor Devices, 2006, Wiley Publication.	
Reference Books:		
[1]	Schroder, Klaus, "Electronic Magnetic and Thermal properties of Solids", Marcel Dekker, New York 1978.	
[2]	Electronic Materials Handbook, ASM International, Materials Park, 1989.	
[3]	Buschow K.H.J.," Handbook of Magnetic Materials", Amsterdam: Elsevier, Volume 15, First Edition December 2003.	