Dual Degree

(B Tech in Metallurgical and Materials Engineering + M Tech in Materials Science and Engineering)

--- Curriculum and Syllabi

DUAL DEGREE

PROGRAM DETAILS FOR SEMESTER 1-6

(Program details of Semesters 7-10 to be uploaded later)

Subject Name	**Code**	**L-T-P**	**Credit**	**Contact Hour**
SEMESTER - I				
Mathematics – I	**MA1L001**	3-1-0	4	4
Physics / Chemistry	**PH1L001 / CY1L001**	3-1-0	4	4
Mechanics / English for Communications or Learning English	**ME1L001 / HS1L001 or HS1L002**	3-1-0 /3-0-2 or 3-1-0	4	4/5 or 4
Electrical Technology / Introduction to Programing and Data Structures	**EE1L001 / CS1L001**	3-1-0	4	4
Introduction to Manufacturing Processes / Engineering Drawing and Graphics	**ME1P001 / CE1P001**	0-0-3/ 1-0-3	2/3	3/4
Physics Laboratory / Chemistry Laboratory	**PH1P001 / CY1P001**	0-0-3	2	3
Electrical Technology Laboratory / Introduction to Programing and Data Structures Laboratory	**EE1P001 / CS1P001**	0-0-3	2	3
EAA	**ID1T001**	0-0-3	1	3
		Total	**22/ 23 +1**	**25/ 27 or 26+3**
SEMESTER – II				
Mathematics – II	**MA1L002**	3-1-0	4	4
Chemistry / Physics	**CY1L001 / PH1L001**	3-1-0	4	4
English for Communication or Learning English / Mechanics	**HS1L001 or HS1L002 /**	3-0-2 or 3-1-0 /3-1-0	4	5 or 4/4

	ME1L001			
Introduction to Programing and Data Structures / Electrical Technology	**CS1L001 / EE1L001**	3-1-0	4	4
Chemistry Laboratory / Physics Laboratory	**CY1P001 / PH1P001**	0-0-3	2	3
Introduction to Programing and Data Structures Laboratory / Electrical Technology Laboratory	**CS1P001 / EE1P001**	0-0-3	2	3
Engineering Drawing and Graphics / Introduction to Manufacturing Processes	**CE1P001 / ME1P001**	1-0-3 /0-0-3	3/2	4/3
EAA – 2	**ID1T002**	0-0-3	1	3
		Total	**23/22+1**	**27or 26/ 25 +3**

Subject Name	**Code**	**L-T-P**	**Credit**	**Contact Hour**
SEMESTER – III				
Basic Electronics	**EC2L005**	3-1-0	4	4
Introduction to Materials Science and Engineering	**ID2L001**	2-0-0	2	2
Introduction to Bio Science and Technology	**ID2L002**	2-0-0	2	2
Numerical Methods	**MA2L007**	3-1-0	4	4
Breadth - I			3	3
Thermodynamics of Materials	**ML2L002**	3-0-0	3	3
Basic Electronics Laboratory	**EC2P005**	0-0-3	2	3
Introduction to Materials Laboratory	**ML2P001**	0-0-3	2	3
Seminar	**ML2S001**	0-0-0	2	0
		Total	**24**	**24**
SEMESTER – IV				
Breadth - II			3	3
Lateral 1			3	3
Environmental Science, Technology and Management	ID2L003	2-0-0	2	2
Materials Processing	**ML2L003**	3-0-0	3	3
Transport Phenomena and Kinetics of Metallurgical Processes	**ML2L004**	3-1-0	4	4

Physical Metallurgy	**ML2L005**	3-0-0	3	3
Materials Processing Laboratory	**ML2P002**	0-0-3	2	3
Physical Metallurgy Laboratory	**ML2P003**	0-0-3	2	3
Thermodynamics of Materials Laboratory	**ML2P004**	0-0-3	2	3
		Total	**24**	**27**
SEMESTER - V				
Breadth - III			3	3
Lateral - II			3	3
Mineral processing	**ML3L001**	3-0-0	3	3
Corrosion and surface engineering	**ML3L002**	3-0-0	3	3
Mechanical properties and testing of materials	**ML3L003**	3-0-0	3	3
Phase transformation of materials	**ML3L004**	3-0-0	3	3
Chemical metallurgy	**ML3L005**	3-0-0	3	3
Mechanical testing & working laboratory	**ML3P001**	0-0-3	2	3
		Total	**23**	**24**
SEMESTER - VI				
Breadth – IV			3	3
Lateral – III			3	3
Materials characterization	**ML3L006**	3-0-0	3	3
Iron and Steel making	**ML3L007**	3-0-0	3	3
Deformation and mechanical working of materials	**ML3L008**	3-0-0	3	3
Introduction to simulation and modeling in materials	**ML3L009**	3-0-0	3	3
Materials characterization laboratory - I	**ML3P002**	0-0-3	2	3
Simulation and modeling laboratory	**ML3P003**	0-0-3	2	3
		Total	**22**	**24**

Details of the courses

Subject Code: EC2L005	Name: Basic Electronics	L-T-P: 3-1-0	Credit: 4
Pre-requisite(s): Nil			
Semiconductor devices: Diode, BJT, MOSFET, their structures and principle of operations; Amplifiers: Functionality, specifications (voltage gain, current gain, input resistance, output resistance, dynamic range, bandwidth, linearity, power efficiency etc.), effect of cascading, various applications and typical circuits; Filters: Low pass, high pass, band pass and band stop filters, single and higher order passive filter topologies (RC and LC); Feedback: Basic concept of negative and positive feedback, application of negative feedback in amplifiers, effect on gain, bandwidth, input resistance, output resistance and desensitivity to parameter variations; Oscillators: Barkhausen criterion, sinusoidal and non-sinusoidal oscillators, applications and typical circuits; Operational amplifier: Differential mode of operation, common mode rejection, typical op-amp specifications, inverting amplifier, non-inverting amplifier, integrator, differentiator, summing amplifier etc., concept of active filters; Power electronics: Half wave and full wave rectification, filtering, regulation with zener diode and linear regulators, switched mode power supply; Digital electronics: Review of Boolean algebra and signed number representation schemes in binary, implementation of Boolean functions using various logic gates, concept of combinatorial and sequential circuits, registers and counters from functional viewpoint, concept of programmable processors and microcontrollers.			
Text/Reference Books: **1.** A. Malvino and D. J Bates *"Electronic Principles,"* Tata McGraw - Hill Education, 2006. **2.** D. A. Neamen, *"Electronic Circuits,"* Tata McGraw - Hill Education, 2006. **3.** Malvino and Brown, *"Digital Computer Electronics,"* Tata McGraw - Hill Education, 2001. **4**. Samuel C. Lee, *"Digital Circuits and Logic Design,"* PHI Learning, 2009. **5**. R. A. Gayakwad, *"Op-Amps and Linear Integrated Circuits,"* PHI Learning, 2009.			

Subject Code: ID2L001	Subject Name: Introduction to Material Science and Engineering	L-T-P: 2-0-0	Credit: 2
Pre-requisite(s): Nil			
Atomic structure and Bonding: Electrons in atoms, Bonding forces and energies, Ionic bonding, Covalent Bonding, Metallic Bonding, Secondary bonding. ***Structure of Crystalline Solids:*** Crystalline and noncrystalline materials, Crystal structures in metals and ceramics, Miller indices ***Imperfections in Solids:*** Point defects, Line defects and dislocations, Interfacial defects, Bulk or volume defects, significance of defects in materials ***Diffusion in materials***: Diffusion mechanisms, Steady and non-steady state diffusion, Factors that influence diffusion ***Phase Diagrams:*** Definitions and basic concepts, Types of phase transformations, Gibbs Phase Rule, Interpretation of phase diagrams ***Mechanical Properties of Materials:*** Elastic deformation, Plastic deformation, Interpretation of tensile stress-strain curves, Measurement of hardness in materials			

Electrical Properties of Materials: Electrical conduction, Semiconductivity, Dielectric Behaviour, Ferroelectric and Piezoelectric Behaviour
Thermal Properties: Heat capacity, Thermal expansion, Thermal conductivity, Thermal stresses
Magnetic Properties: Basic concepts, Diamagnetism, Paramagnetism, Ferromagnetism, Antiferromagnetism, Ferrimagnetism, Influence of temperature, Domains and Hysteresis
Optical Properties: Interaction of light with solids, Optical properties of metals and non-metals

Text Books:

1. *Materials Science and Engineering*, William D. Callister, Jr. Wiley India (P) Ltd.
2. *Introduction to Physical Metallurgy*, Sidney H. Avner, Tata McGraw-Hil.

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Subject Code: ID2L002	**Subject Name: An Introduction to Bioscience & Technology**	**L-T-P: 2-0-0**	**Credit: 2**

Pre-requisite(s): Nil

Cell: The Unit of Life: The concept of cell in the perspective of a whole living body; Concept of cell, tissue system, organ and whole organism. Brief overview of plant and animal cell.
Genes are DNA & Bioinformatics: DNA is the genetic material; Structural aspects–components of DNA and RNA, Nucleosides & Nucleotides (introduction, structure & bonding), Double helical structure of DNA (Watson and Crick model). Mutations change the sequence of DNA, a gene codes for a single polypeptide, recombination occurs by physical exchange DNA, genetic code is triplet. NCBI, protein primary sequence analysis, DNA sequence analysis, sequence alignment, BLAST, multiple sequence alignment; CLUSTALW.
Expression of genetic information**:** Central dogma: The Relationship between genes and protein, Visualization of protein structure using PyMol, The Central dogma; The basic processes of DNA replication, RNA Transcription and Protein translation; Protein function: Enzymes as a case study.
Mutation and Disease: Occurrence, kinds of Mutation, spontaneous & induced Mutation, Mutagens, detection of Mutation, Lethal Mutations, Biochemical Mutations, Phenotypic effects of Mutation, Molecular basis of Mutation, Significance & Practical applications of Mutation.
Immune system:An overview of immune system.

Genetic Engineering: Recombinant DNA technology and basic genetic engineering techniques; some case studies: Cholera Toxin, Bt toxins, GM food, transgenic plants.

Text/Reference Books:

1. Nelson D. L. and Cox M. M. Lehninger *Principles of Biochemistry*, W. H. Freeman & Company.
2. Lodish H.; Berk A. and Kaiser C. A. Molecular *Cell Biology & eBook*, W. H. Freeman & Company.
3. Voet and Voet. *Biochemistry*, Wiley.

Subject Code: MA2L007	**Subject Name: Numerical Methods**	**L-T-P: 3-1-0**	**Credit: 4**

Pre-requisite(s): Maths - I and Maths – II

Introduction to numerical methods: Understanding sources of errors; round-off errors, truncation errors, floating point arithmetic, Convergence

Solution of linear systems: Gauss elimination, Gauss Jordan elimination, Gauss-Seidel method, Diagonal dominance, Banded matrices, storage schemes for banded matrices, skyline solver.

Solution of non-linear systems: Newton Raphson method, Local and global minimum, rates of convergence, convergence criteria, conjugate gradient method.

Ordinary Differential Equations: Taylor series, Euler method, Runge-Kutta method, Finite Difference Method

Partial Differential Equations: Finite Difference Method – Laplace equation, Poison equation, 1-D heat equation, 1-D wave equation.

Text/Reference Books:

1. S. D. Conte and C. de Boor, Elementary Numerical Analysis: An Algorithmic approach, 3rd edition, McGraw-Hill Book Company, New York, 1980
2. D. Dahlquist, and Å.Björck, Translated by Ned Anderson, Numerical Methods, 1stedition, Dover Publication, New York,2003
3. K. E. Atkinson, Introduction to Numerical Analysis, 2nd Edition, John Wiley,New York, 1989
4. C. F. Gerald and P. O. Wheatley, Applied Numerical Analysis, 5th edition, Addison Wesley, Massachusetts, 1994

Subject Code: ML2L002	Subject Name: Thermodynamics of Materials	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			
Introduction : Introduction, Thermodynamics terminology **Thermodynamic Laws**: First law of thermodynamics and its applications, Second law of thermodynamics and its consequences, Combined statement of first and second laws, Third law of thermodynamics **Thermodynamic functions**: Auxiliary functions: Helmholtz free energy, Gibbs free energy, Chemical potential, Maxwells relations, Gibbs-Helmholtz equations. **Phase equilibria in single component system**: Phase equilibria in one-component systems variation of Gibbs free energy with temperature and pressure, Clausius-Clapeyron equation, P-T diagram **Solutions**: Thermodynamics of solutions: Raoults and Henrys Law, activity of a component, Regular solutions, Gibbs-Duhem equation and its application, non-ideal solutions, Sieverts Law, activity and alternative standard states, dilute solutions and interaction parameters. **Electrochemical cells:** Thermodynamics of electrochemical cells, Relation between chemical and electrical driving forces, Nernst equation, Concentration and formation cells **Reaction Equilibria:** Equilibrium constant, Reaction equilibria for (a) homogeneous reactions consisting of gas mixtures, (b) heterogeneous reactions consisting of condensed phases and gas mixtures, Ellingham Diagram. **Free energy composition diagram:** Fundamentals of Free energy-composition diagram for binary systems. Examples of common binary Free energy-composition diagrams: Eutectic, Eutectoid, Peritectic etc. **Phase rules and Phase Diagrams:** Phase rules and its applications, Eutectic and Isomorphous phase diagrams, Lever Rule		
Text/Reference Books: 1. Richard A. Swalin, Thermodynamics of Solids, Wiley-VCH; 2. David R. Gaskell ,Introduction to Thermodynamics of Materials, CRC Press; 5 edition 3. L.Darken and R.W.Gurry ,Physical Chemistry of Metals, McGraw- Hill, New York 4. G. S. Upadhyaya and R. K. Dube, Problems in Metallurgical Thermodynamics and Kinetics, England Pergamon Press Inc 5. D A Porter and K E Easterling, Phase Transformation, CRC Press 6. David Ragone, Thermodynamics of Materials, Wiley, MIT Series Publication			

Subject Code: EC2P005	Subject Name: Basic Electronics Laboratory (for SMS, SIF)	L-T-P: 0-0-3	Credits: 2
Prerequisite(s): Basic Electronics			
Familiarization with electronic components; Familiarization and usage with oscilloscope, signal generator, multimeter; Frequency-response of R-C, C-R and R-L networks; Square-wave testing, V-I characteristics of PN junction diode and zener diode; Voltage Rectifiers; Common-Emitter amplifiers; Analog circuits using OP-AMP; logic gates.			
Text/Reference Books: 1. A. Malvino and D. J Bates "*Electronic Principles*," Tata McGraw - Hill Education, 2006. 2. D. A. Neamen, "*Electronic Circuits*," Tata McGraw - Hill Education, 2006. 3. Malvino and Brown, "*Digital Computer Electronics*," Tata McGraw - Hill Education, 2001.			

4. Samuel C. Lee, "*Digital Circuits and Logic Design*," PHI Learning, 2009.
5. R. A. Gayakwad, "*Op-Amps and Linear Integrated Circuits*," PHI Learning, 2009.

Subject Code: ML2P001	**Subject Name: Introduction to Materials laboratory**	**L-T-P: 0-0-3**	**Credit: 2**
Pre-requisite(s): None			
1. Study of crystal structures and estimation of structural parameters using VESTA software 2. Crushing grinding and sieve analysis 3. Extraction of Silicon from ores (Metallothermic reduction) 4. Casting and microstructure aluminium alloys 5. Slip casting of a ceramic crucible 6. Electrode position of copper 7. Polymer electrolyte fuel cell 8. Cooling curve and phase diagrams 9. Diffusion Couple (Copper -Nickel)			
Text/Reference Books: 1. Laboratory Manual			

Subject Code: ID2L003	**Subject Name: Environmental Science, Technology and Management**	**L-T-P: 2-0-0**	**Credit: 2**
Pre-requisite(s): Nil			
Module-I: Introduction to Environmental System (10-12 Lectures) Components of Earth System: Lithosphere, Cryosphere, Atmosphere, Hydrosphere, Biosphere and Outer space, Science of Weather and Climate systems and their variabilities, Energy, Water, Carbon and Nitrogen Cycles in the Atmosphere, Environmental Pollution (Air, Water, Noise, Soil and Marine), Natural Hazards, Climate Change and Global Warming, Green energy and adaptation to Climate change, Observations-modeling-prediction of environmental systems. Role of ocean on earth's climate system ***Module-II: Green and Sustainable Technology (6-8 Lectures)*** Pollution issues in Industries, Introduction to Green Technology, Emerging and sustainable practices in Electronics, Chemical, Petroleum and Mineral Processing Industries, 12 Principles of Green Chemistry and 12 Principles of Green Engineering. ***Module-III: Environmental Economics and Policies (8-10 Lectures)*** Components of Earth System: Sustainable development, economics of renewable and non-renewable natural resources, Green growth, Environmental valuation, accounting and audit, Carbon Trading, Command and control approach and market based instruments for reducing pollutions, Environmental policies and acts (Air, Noise, Water, Forest, E-waste, Hazardous waste acts). **Text Books:** **Reference Books:**			

Subject Code: ML2L003	Name: Materials processing	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			
Introduction to mineral processing; Basics of solidification processing in metals and alloys: plane front solidification, dendritic solidification, cellular solidification; Semisolid processing of alloys: rheocasting and thixocasting; Different casting processes for engineering components: sand casting, investment casting, pressure die casting and others; Basics of powder processing: preparation of metallic, ceramic and composite powders, Sintering and full density processing; Processing of metal matrix composites, ceramic matrix composites and polymer matrix composites; Processing of advanced materials: nanomaterials, biomaterials; Advanced processing techniques			
Text/Reference Books: 1. B.A. Wills, T.J. Napier-Munn, Mineral Processing Technology, Pub.: Elsevier Science & Technology Books, 7th Edition, 2006. 2. D.V. Subba Rao, Mineral Beneficiation: A Concise Basic Course, Pub.: CRC Press, 2011. 3. M.C. Flemings, Solidification Processing, McGraw Hill, 1974 4. Randall M. German, Powder Metallurgy & Particulate Materials Processing, Metal Powder Industry, 2005			

Subject Code: ML2L004	Name: Transport phenomena and kinetics of metallurgical processes	L-T-P: 3-1-0	Credit: 4
Pre-requisite(s): None			
Transport phenomena: Overview and Fundamentals; Fluid, continuum, stress-tensor vs. pressure-scalar etc; Analogy between transport processes; Heat, mass and momentum balance; Fourier's, Fick's and Newton'slaws;Reynolds Transport Theorem; Scaling laws; laminar & turbulent flow; concept of boundary layer, friction factor; interface heat and mass transfer and dimensionless numbers. **Kinetics**: mass action law; kinetics of homogeneous and heterogeneous reactions with example; Arrhenius Equation; effect of mechanical stressors on reaction kinetics (mechanochemistry applied to materials engineering); electrode kinetics and metal oxidation; nucleation and growth; deoxidation of steel; Further case studies in materials processing.			
Text/Reference Books: 1. D. R. Poirier, G. H. Geiger, Wiley,Transport Phenomena in Materials Processing. 2. A. Ghosh, S. Ghosh, S. (2014). A textbook of metallurgical kinetics. Phi Learning Pvt. Ltd. 3. R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot. Wiley International edition,Transport Phenomena. 4. Julian Szekely, Academic Press, University of Michigan,Fluid flow phenomena in metals processing 5. "Diffusion in solids" P.G. Shewmon, 2nd Edition, 1991, John Wiley and Sons			

Subject Code: ML2L005	Subject Name: Physical Metallurgy	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): Thermodynamics of Materials			
Introduction to metals and alloys: phase, component concepts, crystal structures, single crystal and polycrystalline metals; Crystallography concepts: reference frame conversion, Bravais lattice, close packed planes and directions, Miller indices , unit cell: primitive and non-primitive, introduction to texture; Hume Rothery's rule; Strengthening mechanisms: dislocation, solid solution, precipitation, dispersion, grain-boundary;X-ray diffraction: Bragg's law, applications; Theoretical strength of single crystals; Deformation in single and poly-crystals; Defects: classification (point, line, 2-dimensional and 3 - dimensional); Introduction to dislocation: types, mathematical representation; Orowanequation; Dislocation: stress field, line energy, interactions; Twin: types, mathematical representation; Diffusion: Fick's laws, diffusivity and its physical interpretations, application in heat treatment			
Text/Reference Books: 1. R. E. Reed-Hill, Physical Metallurgy Principles, 4th Edition, 2008, Thomson-Engineering 2. P.G. Shewmon, Diffusion in solids, 2nd Edition, 1991, John Wiley and Sons. 3. D. Hull, D.J. Bacon, Introduction to Dislocations, 5th Edition, 2011, Butterworth-Heinemann			

Subject Code: ML2P003	Subject Name: Physical metallurgy Laboratory	L-T-P: 0-0-3	Credit: 2
Pre-requisite(s): Physical metallurgy			
Microstructure of metals: ferrous alloys (carbon steels), non-ferrous alloys (aluminium, copper, brass), Annealing treatment of a cold worked steel and comparison of the annealed microstructure with the cold worked structure. Microstructure of plain carbon steel with varied carbon content. Normalizing treatment of steel and comparison of the microstructure with annealed structure. Examine the quenched structures of steel – quenched in oil, water and brine solution. Microstructure of quenched and tempered steel: low temperature tempering, medium temperature tempering, and high temperature tempering. Study the recrystallization behaviour and the effects of time and temperature on grain size (grain growth) of a pure metal (Copper). Study the nucleation rate and growth rate of pearlite in eutectoid steel. Jomniny end quench test to study the hardenability of a steel			
Text/Reference Books: 1. ASTM and BIS standards 2. George Vandervoort, Metallography principles and Practice, ASM International 3. J. Goldstein, D. Newbury, D. Joy, C. Lyman, P. Echlin, E. Lifshin, L. Sawyer, J. Michael, Scanning Electron Microscopy and X-ray Microanalysis,2003, Kluwer Academic/Plenum Publisher, New York 4. B.D. Cullity, Elements of X-ray diffraction, 1st Edition, 1956,Addison-Wesley Publishing			

Subject Code: ML2P004	Subject Name: Thermodynamics of materials Laboratory	L-T-P: 0-0-3	Credit: 2
Pre-requisite(s):None			
Bomb Calorimetry: Determination of heat of combustion of fuel, Specific heat capacity calculation etc. **Reduction of Oxides (Equilibrium Composition):**Ellingham Diagrams, Metallothermic and Carbothermic reduction **Sieverts Apparatus (PCT curves):**Hydrogen storage in Alloys (FeTi, etc) **DSC/TGA :**Thermal decomposition of Calcium Carbonate, Roasting of Pyrites **Concentration Cell (Oxygen Sensor, Activity Measurements):** Oxygen Sensors its use in evaluating dissolved gases in liquid metals **Copper Electrodeposition:** Reduction potential determination and concepts of anode and cathodes and electrochemistry **HSC or Thermocalc software:** Equilibrium Compositions, Ellingham diagrams, Reactions Equations and the feasibility.			
Text/Reference Books: 1. Richard A. Swalin, Thermodynamics of Solids, Wiley-VCH; 2. David R. Gaskell ,Introduction to Thermodynamics of Materials, CRC Press; 5 edition 3. L. Darken and R.W.Gurry ,Physical Chemistry of Metals, McGraw- Hill, New York 4. David Ragone, Thermodynamics of Materials, Wiley, MIT Series Publication			

Subject Code: ML3L001	Subject Name: Mineral processing	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			
Introduction of ores and minerals; characterization of particulate materials, estimation of particle size by different methods, representation of size analysis data; sampling, metallurgical accounting and material balance; feed preparation, crushing, screening, grinding and classification, size reduction equipment, work index determination, mineral separation including gravity separation, jigging, spiralling, shaking table concentration etc., electrical and magnetic methods of separation, froth flotation chemistry, froth flotation unit operation, flotation equipment and flotation technology; fine particles processing, separation efficiency versus fine particles fine particles processing techniques; hydrometallurgical operations including chemical leaching ion exchange and solvent extraction, Product preparation operations, including dewatering, thickening, filtration and drying; tailings treatment and effluent processing, tailings pond management and environmental concerns; case studies including sulphide minerals flotation, beach sand processing, uranium ore processing			
Text/Reference Books: • Mineral Processing Technology, B.A. Wills, T.J. Napier-Munn, Pub.: Elsevier Science &Technology Books, 7th Edition, 2009. • Mineral Beneficiation: A Concise Basic Course, D.V. Subba Rao, Pub.: CRC Press, 2011. • Introduction to Mineral Processing, E.G. Kelly and D.J. Spottiswood, Pub.: Wiley, 1982. • Principles of Mineral Processing, M.C. Fuerstenau, Pub.: Society of Mining, Metallurgy and Exploration, 2003.			

Subject Code: ML3L002	Name: Corrosion and Surface Engineering	L-T-P: 3-0-0	Credit: 3
Pre-Requisites: Thermodynamics of Materials (course)			
Introduction; electrochemical and environmental aspects of corrosion; types of corrosion (galvanic, pitting, crevice, fretting etc); Corrosion testing; material specific corrosion (metals and alloys, plastics and ceramics); corrosion prevention; case studies on environment specific degradation of materials. Introduction: Engineering components, surface dependent properties and failures, importance and scope of surface engineering, Surface and surface energy: Structure and types of interfaces, surface energy and related equations. Surface engineering: classification, definition, scope and general principles. Surface engineering by material removal: Cleaning, pickling, etching, grinding, polishing, buffing / puffing (techniques employed, its principle). Role and estimate of surface roughness. Surface engineering by material addition: From liquid bath - hot dipping (principle and its application with examples).: Electrodeposition/plating (theory and its scope of application).Surface modification of steel and non ferrous components: Pack carburizing (principle and scope of application). Surface modification using liquid/molten bath: Cyaniding, liquid carburizing (diffusion from liquid state) (principle and scope of application). Surface modification using gaseous medium: Nitriding carbonitriding (diffusion from gaseous state) (principle and scope of application). Surface engineering by energy beams: Laser assisted microstructural modification – Laser assisted compositional modification – surface cladding, composite surfacing and similar techniques. Surface engineering by energy beams: Electron beam assisted modification and joining. Ion beam assisted microstructure and compositional modification. Surface engineering by spray techniques: Flame spray (principle and scope of application).: Plasma coating (principle and scope of application). Surface engineering by spray techniques: HVOF, cold spray (principle and scope of application). Characterization of surface microstructure and properties (name of the techniques and brief operating principle). Evaporation - Thermal / Electron beam, Sputter deposition of thin films & coatings – DC & RF, Sputter deposition of thin films & coatings –Chemical vapor deposition and PECVD, Plasma and ion beam assisted surface modification, Surface modification by Ion implantation and Ion beam mixing.			
Text/Reference Books: • M. G. Fontana, Corrosion Engineering, Tata McGraw-Hill Education, 2005. • Surface Engineering & Heat Treatment By: P.H Morton I.I.T, Brooke field, 1991. • Metals Handbook Ninth Edition, Vol.5, Surface Cleaning,Finishing & Coating, ASM, Metals Park Ohio, 1982.			

Subject Code: ML3L003	Subject Name: Mechanical properties and testing of materials	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): Introduction to Materials Science and Engineering			
Elements of theory of elasticity: Elastic and plastic behaviour; Concept of Strain and Stress; States of Stress in two and three dimensions; Elastic Stress-Strain Relations; **Yielding and Plastic Deformation:** Hydrostatic and deviatoricstress;octahedral stress; yield criteria and yield surface; texture and distortion of yield surface; limitation of engineering strain at large deformation; true stress and true strain; effective stress; effective strain; flow rules; strain hardening;Ramberg-Osgood equation; stress -strain relation in plasticity; plastic deformation of metals and polymers			

The Tension Test: Engineering Stress-Strain Curve, True-Stress-True-Strain Curve, Instability in Tension, Stress Distribution at the Neck, Ductility measurement in Tension Test, Effect of Strain-Rate on Flow Properties; Effect of Temperature on Flow Properties; Influence of Testing machine on Flow properties; Constitutive equations; Stress Relaxation Testing; Notch Tensile Test; Extraction of elastic and plastic material properties of different materials from uniaxial loading experiments
The Hardness/Indentation Test: Types of indenters; Hardness Tests: Knoop, Vickers, Brinell, Meyers, Rockwell; Load vs displacement curve obtained during nanoindentation test; Analysis of nanoindentation test data
The Torsion Test: Mechanical Properties in Torsion, Torsional Stresses for Large Plastic Strains, Types of Torsion Failures, Comparison between Torsion test and tension test
Deformation under cyclic load - Fatigue: S-N curves; low and high cycle fatigue; life cycle prediction; fatigue in metals, ceramics and polymers
Introduction to fracture toughness testing: Strain energy release rate, stress-intensity factor, fracture toughness and design; KIcPlain Strain Toughness Testing; ; Impact testing; Indentation fracture toughness testing
Wear testing: recognition of different lubrication regimes, seizure mechanisms, lubricant behaviour, and effect of load, temperature, and sliding speed on friction and wear properties of bearing materials
Dynamic Mechanical Analysis: Introduction to concepts of anelasticity and viscoelasticity; measurement of storage modulus and loss modulus

Text/Reference Books:

1. Mechanical Metallurgy, Third edition, Fifth Reprint, George E. Dieter, Indian edition, McGraw-Hill Education (India) Private Limited, 2014.
2. Mechanical Testing of engineering Materials, First edition, Kyriakos Komvopoulos, University Readers, 2011.
3. Deformation and Fracture Mechanics of Engineering Materials, Fifth Edition, Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg, Wiley India Edition, 2013.
4. Nanoindentation, Third Edition, Anthony C. Fischer-Cripps, Springer, 2011.
5. Dynamic Mechanical Analysis: A Practical Introduction, First Edition, Kevin P. Menard, CRC Press, 2008.
6. Friction, Wear, Lubrication: A Textbook in Tribology, Kenneth C. Ludema, CRC Press, 1996.

Subject Code: ML3L004	**Subject Name: Phase transformation of materials**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): Thermodynamics of Materials, Physical metallurgy

Temperature composition diagram, Binary phase diagram construction; Interfaces : interphase and grain boundary concepts; Interfacial movement: low and high angle boundaries; Solidification: homogenous and heterogenous nucleation conditions, rate of nucleation, growth, Scheil equation derivation, constitutional and thermal super-cooling, dendritic solidification principles, eutectic solidification; Diffusional transformations: Nucleation, heterogenous nucleation sites, nucleation rate, growth, surface energy effects; Introduction to spinodaldecomposition, eutectoid and massive transformations; Non-diffusional transformations: nucleation conditions, growth; Martensitic transformation characteristics

Text/Reference Books:

- D.A. Porter, K. E. Easterling and M.Y. Sherif, Phase Transformation in Metals and Alloys, 3rd Edition,

Subject Code: ML3L005	**Subject Name: Chemical metallurgy**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite(s): None			
Introduction to Reaction Engineering, Basic Concepts in Chemical Kinetics, Collection and Analysis of Rate Data, Non-ideal flow, Diffusion and Reaction in Porous Catalysts, Behaviour of chemical reactors: ideal and non-ideal flow. Introduction to ores and minerals; ore beneficiation; routes to metal extraction; material and heat balance in extractive processes; thermochemistry, multicomponent chemical equilibrium, activity, Gibbs Free energy; High temperature melts-structure and properties; Ellingham diagram; phase diagrams; unit processes in metal extraction-reactor types, mixing and residence times; reaction rates-heterogeneous reactions, diffusion and convection; vacuum distillation and metallurgy of volatile metals; hydrometallurgy; pyrometallurgy of metal oxides; matte smelting; metal refining; case studies in metal extraction process			
Text/Reference Books: • A. Ghosh, & H. S. Ray.Principles of extractive metallurgy, New Age International,1999. • T. Rosenqvist, Principles of extractive metallurgy, Tapir Academic Press, 2004.			

Subject Code: ML3P001	**Subject Name: Mechanical testing & working Laboratory**	**L-T-P: 0-0-3**	**Credit: 2**
Pre-requisite(s): Mechanical properties and testing of Materials			
Tensile/Compression Test: Effect of temperature on tensile/compressive behaviour of steels/aluminium alloys; Determination of friction factor; Determination of constitutive equations of metal flow, Studying the effect of strain rate. Comparison of the stress-strain curves of aluminium alloys, steels, polymers and composites, Study of the effect of specimen size (h/D ratio) and effect of lubrication. Ring compression test Hardness measurements: Rockwell, Brinell, Vickers (Macro- and micro-hardness) Micro/Nano-indentation tests: Determination of elastic modulus, hardness and indentation fracture toughness of brittle ceramics and glasses using instrumented micro/nano-indenter. Fatigue test: High-cycle and low-cycle fatigue tests; Determination of S-N curve for a steel sample, and observation of fracture surfaces. Charpy Impact tests: Study of impact energy of steels at low and ambient temperatures, and observation of fracture surfaces Fracture toughness test: Determination of fracture toughness under plane strain by three point bend tests on single edge notch bend tests, and observation of fracture surfaces. Determination of fracture toughness of thin plates under plane stress conditions			
Text/Reference Books: • ASTM Standards, 2008.			

- K. Komvopoulos, Mechanical Testing of Engineering Materials, University Readers, 2010.
- C. S. Rangan, G. S. Sharma, and V. S. V. Mani, Instrumentation: Devices and Systems, McGraw Hill Education (India) Private Limited; 2 edition, 2001.

Subject Code: ML3L006	**Name: Materials Characterization**	**L-T-P: 3-0-0**	**Credit:3**

Pre-Requisite(s): None

Introduction: Importance of Characterization in Metallurgy and Materials Engineering, Structural and Functional Characterizations, Review of Crystallography.
X-ray Diffraction: Laue Equations and Bragg's Law, Reciprocal space, Ewald sphere construction, Diffraction analysis: Atomic scattering factors, scattering by the unit cell, Structure factor, diffraction intensities, X-diffraction methods- Powder diffraction, single crystal Laue diffraction, rotating single crystal method, Thin film analysis, Scherrer formula and grain size determination.
Optical Microscopy: special microscopy techniques.
Scanning Electron Microscopy: Fundamentals principles of SEM, sample preparation techniques, SE and BSE imaging modes, X-ray mapping and Fractography.
Transmission Electron Microscopy: Wave properties of electron, electron-matter interactions, Ring patterns, spot patterns, Laue zones, Resolution limitation and lens aberrations, The origin of contrast: mass-thickness contrast, diffraction contrast and crystal defect analysis, BF, DF, sample preparation techniques.
Thermal Analysis: Thermometric Titration (TT), Thermal Mechanical Analysis (TMA), Differential Scanning Calorimetric (DSC), Thermal Gravimetric Analysis (TGA), Differential Thermal Analysis (DTA).
Introduction to Specialized techniques: AES, FIB, PPMS, Raman spectroscopy
Non-destructive testing of materials: Theory of mechanical waves, Application in Ultrasonic testing, die penetration test, magnetic particle inspection, eddy current testing, radiography

Texts and References:

1. L.V. Azaroff,Introduction to solids, McGraw-Hill Book Company, 2001.
2. B.D. Cullity and S.R. Stocks, Elements of X-ray diffraction, Addison-Wesley Publishing Co., 1959.
3. M.J. Buerger, Elementary Crystallography, 1956.
4. E.J. Mittemeijer, Fundamentals of Materials Science-the microstructure-property relationship using metals as model systems, Springer, 2010.
5. D. B. Williams and C. Barry Carter, Transmission Electron Microscopy: A Textbook for Materials Science, Springer; 2nd edition 2009.
6. Goldstein, J., Newbury, D.E., Joy, D.C., Lyman, C.E., Echlin, P., Lifshin, E., Sawyer, L., Michael, J.R., Scanning Electron Microscopy and X-ray Microanalysis: Third Edition, Springer US, 2003.
7. Gradiner and Graves(Ed.), Practical Raman Spectroscopy, Springer, 1989.
8. GüntherHöhne, Wolfgang F. Hemminger , H.-J. Flammersheim, Differential Scanning Calorimetry, Springer, 2003.

Subject Code: ML3L007	Subject Name: Iron and Steel making	L-T-P: 3-0-0	Credit: 3
Pre-requisites: Thermodynamics of materials (course), Transport phenomena and kinetics of metallurgical processes (course)			
Introduction; blast furnace over view and statistics; raw material and mass balance; coal to coke; requirement on coke; sintering; the process of iron making-burden descent and reactions; gas channels and burden distribution; hot metal and slag control; Stops and startups; blow down; pig iron; casting. Steel making in India/world; Classification of steel making processes; production of primary and secondary steel; slag chemistries and refining; BOF process and hybrid processes of steel making; raw material and efficiency in steel making; direct (without blast furnace) production of primary steel- HIsarna steelmaking process; secondary steel making; ingot solidification and continuous casting			
Text/Reference Books: 1. Ahindra Ghosh, Amit Chatterjee, Iron making and steelmaking: Theory and practice, Eastern economy edition, PHI Learning Pvt. Ltd., 2008 2. Steel making, A.K. Chakrabarti, Prentice-Hall of India Pvt. Ltd, 2007 3. Brahma Deo and Rob Boom, Fundamentqls of Steelmaking Metqallurgy, Prentice Hall, UK, 1993.			

Subject Code: ML3L008	Name: Deformation and mechanical working of materials	L-T-P: 3-0-0	Credit: 3
Pre-requisites: Mechanical properties and testing of materials			
Introduction to deformation behaviour: Concept of stresses and strains; engineering stresses and strains; different types of loading and temperature encountered in applications; Review of theory of plastic deformation; Introduction to viscoplastic deformation **Deformation at high temperature:** Time dependent deformation - creep; different stages of creep; creep and stress rupture; creep mechanisms and creep mechanism maps; creep under multi-axial loading; microstructural aspects of creep and design of creep resistant alloys; high temperature deformation of ceramics and polymers Fundamentals of metal working: Classification of forming processes, mechanics of metal working, temperature and strain rate effects, instability and flow localization, shear banding, workability, microstructure and texture evolution, friction and lubrication, residual stress. Forging: Closed-die and open-die forging, forging equipment, mechanics. Rolling: Terminology of rolled products, different kinds of rolling mills, forces and geometric relationships, variables affecting roll pressure, power and friction, theories of cold and hot rolling, roll pass design. Extrusion: Direct and indirect extrusion, impact extrusion, hydrostatic extrusion, equipment, extrusion variables, extrusion pressure. Wire and tube drawing: Processes and equipments, hydrodynamic lubrication, draw stress, factors affecting draw stress and reduction. Sheet metal forming: Different forming methods, forming limit criteria Non-conventional methods: Powder performs forging, superplastic forming, high energy rate forming, mushy state forming, forming of plastics.			

Text/Reference Books:

1. G.E. Dieter: Mechanical metallurgy, McGraw Hill Book Company, New Delhi, 1986.
2. J.N. Harris: Mechanical Working of Metals- Theory and Practice, Pergamon Press, Oxford, 1983.
3. J. Lin, D. Balint, M. Pietrzyk: Microstructure evolution in metal-forming processes, Woodhead Publishing Limited, 2012.
4. W. F. Hosford and R. M.Caddell: Metal Forming: Mechanics and Metallurgy, Prentice-Hall, 2011.
5. A.S.M. Handbook Vol. 14, Forming and Forging, ASM International
6. J. G. Lenard, Metal Forming Science and Practice, Elsevier Science Ltd., U.K, 2002

Subject Code: ML3L009	**Name: Introduction to simulation and modeling in materials**	**L-T-P:3-0-0**	**Credit:3**

Pre-Requisites: Numerical methods, Physical Metallurgy

Monte Carlo methods: Two state Potts model (Ising model): Hamiltonians, Dynamics and boundary conditions, Temperature and anisotropy. Q-state Potts model: self-ordering, Boundary energy and mobility, pinning system and stored energy. Applications: Grain growth, Recrystallization and Zener pinning
Reverse Monte Carlo analysis: Error in data and chi-square distribution, minimisation of chi-square, forward vs. reverse Monte Carlo analysis.
Genetic algorithms (GA): Understanding Darwin's theory, Gene, Chromosome, fitness function and survival of fittest, applications of GA in materials science and granular media
Overview of molecular dynamics and discrete element modelling
Introduction to advanced topics: Finite element methods. Phase field modelling, Integrated computational materials engineering (ICME) and materials genome initiative (MGI)

Text/Reference Books:

1. K. Janssens, G. Frans, D. Rabbe, B. Nestler, E. Kozeschnik, M, Miodownik, "Computational Materials Engineering: An introduction to microstructure evolution", Academic Press, Burlington, 2007.
2. J. M. Haile, "Molecular dynamics simulations: Elementary methods", John Wiley and Sons, Inc., New York.1992.

Subject Code: ML3P002	**Name: Materials Characterization Laboratory - I**	**L-T-P:0-0-3**	**Credit: 2**

Pre-Requisites: Materials Characterization (course)

1. Phase identification in cubic/non-cubic materials using powder X-ray diffraction, visualization of the structure and calculation of structural parameters
2. Size and strain estimation in ultra-fine grained materials using powder X-ray diffraction
3. Quantitative image analyses of microstructures of dual phase materials
4. Magnification calibration in SEM
5. Effect of acceleration voltage on the resolution in SEM

6. Microstructure study of ferrous and non-ferrous metals and alloys using SEM: Secondary and Backscattered Imaging
7. Effect of Sample tilting on imaging in SEM
8. Observation of microstructure of fracture surfaces and fibers/powders using SEM
9. Determination of chemical composition of commercial alloys by Energy Dispersive Spectroscopy
10. High resolution imaging for nanostructured materials in SEM
11. Determination of phase transition temperatures by differential scanning calorimetry and differential thermal analysis
12. Non-destructive testing of materials: Ultrasonic testing, A/B scan to identify defects, measure thickness of materials, inspection of corrosion

Subject Code: ML3P003	**Name: Simulation and modeling laboratory**	**L-T-P: 0-0-3**	**Credit:2**

Pre-Requisites: Introduction to simulation and modeling in materials (course)

Review of programming in C: Basics, pointers, functions, pre-processor, Arrays
Introduction to programming in Matlab®: Matrices and their manipulations, Image processing basics.
Microstructure simulations using Monte-Carlo: Vanilla algorithm for Ising model using Glauber and Kawasaki dynamics, Simulation using Q state Potts model
Developing basic codes for: Discrete Element modelling, Genetic algorithm
Molecular dynamics modelling using LAAMPS

Text/Reference Books:

1. S. D. Conte and C. de Boor , Elementary Numerical Analysis: An Algorithmic approach, Mc Graw-Hill Book Company, New York, 1980.
2. D. Dahlquist, and A. Bork, Numerical Methods, Dan Prentice-Hall, Englewood Cliffs, NJ,. 1974.
3. K. Janssens, G. Frans, D. Rabbe, B. Nestler, E. Kozeschnik, M, Miodownik, Computational Materials Engineering: An introduction to microstructure evolution, Academic Press, Burlington, 2007.

Dual Degree

in

Metallurgical and Materials Engineering

Subject Name	Subject Code	L-T-P	Credit	Contact Hour
SEMESTER - VII				
Light metals and alloys	ML4L001	3-0-0	3	3
Elements of Electroceramics	ML4L002	3-0-0	3	3
Polymers and nanocomposites	ML4L003	3-0-0	3	3
Materials Characterization	ML6L003	3-1-0	4	4
Materials Characterization Laboratory-II	ML4P001	0-0-3	2	3
Process control and instrumentation laboratory	ML4P002	0-0-3	2	3
Industrial training defense	ML4T001	0-0-0	2	0
Project - I	ML4D001	0-0-6	4	0
		Total	**23**	**19**
SEMESTER - VIII				
Modeling and Simulation of Materials	ML6L004	3-1-0	4	4
Phase Transformation in Materials	ML6L005	3-0-0	3	3
Modelling and Simulation Laboratory	ML6P002	0-1-3	4	4
Elective-I	ML6LXXX	3-0-0/3-1-0	3/4	3/4
Project - II	ML4D002	0-0-9	6	0
		Total	**20/21**	**14/15**
SEMESTER - IX				
Materials Processing	ML6L002	3-1-0	4	4
Advanced Thermodynamics and Kinetics	ML6L001	3-1-0	4	4
Research Review Paper	ML6D002	0-0-0	4	0
Thesis-Part - I	ML6D001	0-0-0	12	0
		Total	**24**	**8**
SEMESTER - X				
Research Review Paper	ML6D004	0-0-0	4	0
Thesis-Part - II	ML6D001	0-0-0	13	0
		Total	**17**	**0**
	Total Credits		**222/230(+2)**	**190/199(+6)**

List of Elective Subjects - Elective – I

Subject Name	Code	L-T-P	Credit	Contact Hour
Elective – I to V				
Advances in Materials Science	ML6L006	3-0-0	3	3
Structure of Materials and X-ray Diffraction	ML6L007	3-0-0	3	3
Materials Recycling and Waste Management	ML6L008	3-0-0	3	3
Advanced Physical Metallurgy	ML6L009	3-0-0	3	3
Materials Design	ML6L010	3-0-0	3	3
Ceramic Materials	ML6L011	3-0-0	3	3
Biomaterials Processing and Applications	ML6L012	3-0-0	3	3
Surface Engineering	ML6L013	3-0-0	3	3
Powder Materials and Processing	ML6L014	3-0-0	3	3
Heat Treatment of Materials	ML6L015	3-0-0	3	3
Extractive Metallurgy	ML6L016	3-0-0	3	3
Mineral Beneficiation	ML6L017	3-0-0	3	3
Principles of Materials Engineering	ML6L018	3-0-0	3	3
Mechanical Behavior of Materials	ML6L019	3-0-0	3	3
Transport Phenomena	ML6L020	3-0-0	3	3
Corrosion Science and Engineering	ML6L021	3-0-0	3	3
Diffusion in Solids	ML6L022	3-0-0	3	3
Advanced Joining Processes	ML6L023	3-0-0	3	3
Granular Materials	ML6L024	3-0-0	3	3
Advanced Composites	ML6L025	3-0-0	3	3
Functional Oxides: Structure and Properties	ML6L035	3-0-0	3	3

Subject Code: ML4L001	**Name: Light metals and alloys**	**L-T-P: 3-0-0**	**Credit:3**

Pre-Requisites: Physical metallurgy

Introduction and classification of light metals and alloys; Synthesis of light metals and alloys; Ingot metallurgy, semi-solid processing, spray deposition, mechanical alloying, plasma processing, vapour deposition, and electron beam processing of light metals; Titanium alloys: Production of Ti, processing, properties, and applications (aerospace etc.) of Ti-alloys; Magnesium alloys: Production of Mg, melting and casting, recent trends in Mg alloys, application; Aluminium alloys: Production of Al, wrought and cast Al-alloys, applications; New and advanced technique for processing of Aluminium, Magnesium and Titanium alloys; Metal matrix composites based on Al, Mg and Ti alloys; Recent advances in automotive, naval and aerospace applications

Texts/Reference Books

1. J. Polmear, Light Alloys: Metallurgy of the Light Metals, Wiley, 1995.
2. ASM Handbook, Vol. 3.Properties and selection: Non-Ferrous alloys and special purpose materials,1992.

Subject Code: ML4L002	Name: Elements of electroceramics	L-T-P: 3-0-0	Credit: 3

Pre-Requisites: Introduction to Materials Science and Engineering; Thermodynamics of Materials; Physical Metallurgy.

Introduction: Brief review crystal structure of materials. Review of selected topics of introductory solid state physics. Structure of crystalline ceramics: Structure rules with special emphasis on radius ratio concept; Oxide structures, Silicate structures; Derivative structures and polymorphism. Synthesis methods of ceramic materials :Bulk preparation routes; Thin film preparation methods; Defect chemistry and defect equilibria: Point defects; Kröger–Vink notation; Defect reactions; Defect equilibria; Defect equilibrium diagram. Conduction in ceramics: Diffusion; Mobility and diffusivity; Ionic Conductors and applications. Linear dielectric ceramics: Theory of polarization, Frequency dependence; Dielectric relaxation; Equivalent circuit representation and impedance analysis; Dielectric breakdown. Non-linear dielectric ceramics: Classifications; Piezoelectrics: Direct and converse piezoelectric effects, Pyroelectrics; Ferroelectrics: Curie-Weiss law, domains; Applications. Magnetic Materials: Magnetism- classical and quantum approaches: diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism and ferrimagnetism; Structures of magnetic ceramics; Applications. Multiferroic and magnetoelectric ceramics: Theory; Magnetoelectric coupling; Type I and Type II multiferroics; Applications. Superconducting ceramics: Meissner effect; Type I and II Superconductors ;High temperature superconductivity in ceramics; Applications.

Texts/Reference Books

1. Introduction to Ceramics, 2nd Edition, W. D. Kingery, H. K. Bowen, D. R. Uhlmann, John Wiley and Sons, 1976.
2. Principles of Electronic Ceramics, by L. L. Hench and J. K. West, New York, NY: John Wiley, 1990
3. Electroceramics: Materials, Properties, Applications, by A. J. Moulson and J. M. Herbert, Wiley-Blackwell; 2nd Edition, 2003.
4. Nonstoichiometry, Diffusion and Electrical Conductivity in Binary Metal Oxides (Science & Technology of Materials), P.K. Kofstad, New York, Wiley-Interscience, 1972.
5. Solid State Physics, A.J. Dekker, Prentice-Hall, 1969
6. Transition Metal Oxides: An Introduction to Their Electronic Structure and Properties, P.A. Cox, Oxford University Press, 2010 (republished)
7. Non-stoichiometric Oxides, O. ToftSørensen, Academic Press, 1981

Subject Code: ML6L001	**Name: Advanced Thermodynamics and Kinetics**	**L-T-P: 3-1-0**	**Credit: 4**
Pre-requisite(s): None			
Thermodynamics: First law, Second law, Entropy, Heat engine, Cyclic process, Entropy criteria for equilibrium, Combination of 1st and 2nd laws; Maxwell's Relation, Gibb's-Helmholtz equation, Thermal expansivity and compressibility; Third law: Hess law, Kirchhoff's law; Phase Equilibria: Clausius–Clapeyron equation, solid-liquid/vapor-condensed phase equilibria, Fugacity; Solution Thermodynamics: Raoult's law, Henry law, Gibb's–Duhem equation, Configurational entropy, Regular solution, Excess function, Thermodynamics of point defects; Free energy: Evaluation of phase diagram, Gibb's phase rule, Lever rule; Thermodynamics of Metallurgical Reaction: Ellingham diagram, Predominance area diagram; Kinetics: Laws of kinetics, Theory of reaction rates, Grain growth kinetics, Precipitate nucleation and growth kinetics, Concept and modelling of diffusion controlled growth. **Texts / Reference Books:** 1. David R. Gaskell, *Introduction to thermodynamics of materials* 2. C.H.P. Lupis, *Chemical thermodynamics of materials* 3. G.S. Upadhyaya and R.K.Dube, *Problems in metallurgical thermodynamics and kinetics*			

Subject Code: ML6L002	**Name: Materials Processing**	**L-T-P: 3-1-0**	**Credit: 4**
Pre-requisite(s): None			
Solidification processing: Plane front solidification, cellular solidification, cellular-dendritic transition, Theories of regular and irregular eutectic growth, Rheocasting, Thixocasting, casting of composites; Powder processing: preparation of metallic, ceramic and composite powders; Sintering and full density processing; Metal forming processes: Deformation theories, Applications in rolling, forging, extrusion, machining; Processing of new materials: nanomaterials and biomaterial; Joining of materials: Fundamentals of liquid and solid state joining, friction stir welding, joining of similar and dissimilar materials; Processing of minerals, particulate materials; characterization of particles; crushing, grinding and classification; minerals separation using gravity techniques, electrical and magnetic methods, froth flotation, de-watering using thickening, filtration and drying operations; effluent processing and tailings disposal; Processing of ceramics: Crystal Systems, Amorphous			

Systems - Glass, Phase Equilibria, Sintering of ceramics, Microstructure of Ceramics, Mechanical Properties, Thermal Properties, Optical Properties, Electrical and Magnetic Properties, Chemical Properties Traditional Ceramic Raw Materials, Non-Traditional and Special Ceramic Raw Materials, Glass ceramics, Bio implants, Advanced ceramics; Material processing from solid waste from metal industry and thermal power plants.

Texts / Reference Books:

1. Porter, Easterling and Sherif, *Phase Transformation in metals and alloys*
2. Randall M. German, *Powder Metallurgy & Particulate Materials Processing*
3. WD Kingery, HK Bowen, DR Uhlmann, *Introduction to ceramics*
4. B.A. Wills and T. Napier-Munn, *Wills' Mineral Processing Technology*
5. E.G. Kelly and D.J. Spottiswood, *Introduction to Mineral Processing*

Subject Code: ML6L003	**Name: Materials Characterization**	**L-T-P: 3-1-0**	**Credit: 4**

Pre-requisite(s): None

Importance of characterization studies in materials science – applications in industry and research; Review of materials science fundamentals; Mechanical waves and Ultrasonic testing; Principles of image formation and optical aberrations; Sample preparation techniques for optical and scanning electron microscopy; Optical metallographic – phase contrast, Nomarski contrast techniques; Scanning electron microscopy: beam-sample interaction, Interaction volume concept, WDS, EDS, EPMA techniques and their application; X-ray diffraction – application in macro-texture, crystal structure and residual stress determination; Atomic absorption spectroscopy; Optical emission spectroscopy; X-ray fluorescence spectroscopy; Electron energy loss spectroscopy; Gas chromatography –application in dissolved gas analysis; Differential scanning calorimetry; Thermo gravimetric analysis; Surface analysis methods: AES, XPS; Transmission electron microscopy: sample preparation, bright field and dark field imaging, Kikuchi line formation and selected area diffraction analysis; Orientation imaging microscopy: sample preparation, application in micro-texture, phase, residual stress and grain size determination; Mass spectrometry.

Texts / Reference Books:

1. J. Goldstein, D.E. Newbury, D.C. Joy, C.E.Lyman,P.Echlin,E. Lifshin, L. Sawyer, J.R. M L Sawyer, J R Michael, *Scanning Electron Microscopy and X-ray Microanalysis*.
2. ASM Handbooks Online
3. David B. Williams, C.Barry Carter, *Transmission Electron Microscopy: A Textbook for Materials*

Science (4 Vol. Set).
4. G. Hohne, W.F. Hemminger, H. –j Flammersheim, *Differential Scanning Calorimetry.*
5. O. Engler, V. Randle, *Introduction to Texture Analysis: Macrotexture, Microtexture, and Orientation Mapping*.
6. B.D. Cullity, C.R. Stock, *Elements of X-Ray Diffraction*

Subject Code: ML4P001	**Name: Materials Characterization Laboratory - II**	**L-T-P:0-0-3**	**Credit:2**

Pre-Requisites: Materials Characterization (course)

Conductivity of ionic solids
To study resistivity variation of NaCl as a function of temperature and estimate the energies related to vacancy migration and vacancy formation (in eV units)
Electrical characterization of semiconductors
To study room temperatureresistivity, carrier concentration and carrier mobility ofann- or p- type semiconductor having a majority carrier, either electrons or holes (using Hall measurement set-up).
To study temperature dependence ofresistivity in germanium and to estimate the band gap energy (Eg) in germanium (Ge) (using Four-point probe set-up with furnace)
Dielectric behaviour of Barium Titanate
To study thevariation of dielectric constant as a function of temperature and to determine the ferroelectric Curie temperature in barium titanate.
To study the temperature dependence of impedance property of polycrystalline ceramic sample (SrTiO3)
Magnetic Hysteresis of Ni.
To study the magnetization behaviour of nickel when subjected to an alternating magnetic field and to report (i) hysteresis curve (ii) HC (iii) BS (iv) Br.
Ferroelectric and Piezoelectric Properties of BaTiO3
To study the electric polarization behaviour of BaTiO3 subjected toalternating electric fields with varied frequencies and to report (i) Frequency dependence of polarization hysteresis curve (ii) EC (iii) PS (iv) Pr.
To study the polarization fatigue behaviour in BaTiO3
To study the piezoelectric behaviour and determination of piezoelectric constant of BaTiO3
Photovoltaic Effect
To estimate the efficiency of standalone Solar photovoltaic system
Measurement of current – voltage characteristics of crystalline silicon solar cell (i) in dark and (ii) under illumination
Optical Properties of Materials
a. To study the optical absorption behaviour and estimate the optical band gap of thin film of SrTiO3 on Si substrate.

Subject Code: ML6L004	**Name: Modelling and Simulation of Materials**	**L-T-P: 3-1-0**	**Credit: 4**
Pre-requisite(s): None			
Basics of modeling and simulations, Empirical and phenomenological modeling, Population balance models, Kinetic models, Stochastic models, Matrix models, Discrete size discrete time models, Discrete size continuous time models, Continuous size continuous time models, Modeling of flotation networks and simulation of complex flotation circuits, Material balance over complex minerals flow sheets, Physical modeling, Mathematical modeling; Data modeling as a new type of modeling, Reverse Monte-Carlo Analysis (RMCA): Reconstruction of 3-D atomic ensemble from diffraction data, Discrete Element Modeling (DEM), Finite Element Method (FEM) and its application in materials science, Ab-initio simulations, Phase-field modelling. **Texts / Reference Books:** 1. K. Janssens, G. Frans, D. Rabbe, B. Nestler, E. Kozeschnik, M, Miodownik, *Computational Materials Engineering- An Introduction to Microstructure Evolution*. 2. K. KesavaRao, Prabhu R. Nott, *An Introduction to Granular Flow*. 3. Dominik Marx, JürgHutter, *Ab Initio Molecular Dynamics: Basic Theory and Advanced Methods.*			

Subject Code: ML6L005	**Name: Phase Transformation in Materials**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite(s): None			
Diffusion and thermodynamics of surfaces and interfaces, Irreversible thermodynamics, Kinetics of phase transformations, Salient features of solid-solid and solid-liquid phase transformations, Ingot, Continuous cast and fusion weld microstructure, Defects during solidification, Diffusional transformations in steel, Precipitation phenomena in age hardened alloys, Order-disorder transformation, Martensitic transformations. **Texts / Reference Books:**			

1. D. A. Porter and K. E. Easterling, *Thermodynamics of solids, R.A. Swalin,Phase transformations in metals and alloys*.
2. P. G. Shewmon, *Diffusion in solids*.
3. R. E. Reed-Hill, *Physical metallurgy principles.*
4. R. w. Cahn and P Haasen, *Physical Metallurgy (4th Ed.)*
5. M. P. Allen, D. J. Tildesley, *Computer Simulation of Liquids*.
6. J. M. Haile, *Molecular Dynamics Simulation: Elementary Method.*

Subject Code: ML6P002	**Name: Modeling and Simulation Laboratory**	**L-T-P: 0-1-3**	**Credit: 3**

Pre-requisite(s): None

General introduction and programming protocols, Discrete element modeling, Contact rule for soft particles, Molecular dynamics simulation: hard and soft core potentials, Lenard-Jones potentials, Equation of motion, Conservation laws, Euler method, Runga-Kutta method, Predictor corrector method, Verlet algorithm; Monte-Carlo methods, Reverse Monte-Carlo analysis and reconstruction of the atomic ensemble from the diffraction data, Optimization techniques such as Genetic Algorithm (GA) and Simulated Annealing (SA).

Texts / Reference Books:

1. K. Janssens, G. Frans, D. Rabbe, B. Nestler, E. Kozeschnik, M. Miodownik *Computational Materials Engineering – An Introduction to Microstructure Evolution.*
2. M. P. Allen, D. J. Tildesley, *Computer Simulation of Liquids*.
3. J. M. Haile, *Molecular Dynamics Simulation: Elementary Methods*.
4. K. KesavaRao, Prabhu R. Nott, *An Introduction to Granular Flow*, K. KesavaRao.
5. Dominik Marx, JürgHutter, *Ab Initio Molecular Dynamics: Basic Theory and Advanced Methods.*

Subject Code: ML6L006	Name: Advances in Materials Science	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Fundamentals of structure in crystalline solids, Imperfections in materials, Characterization Techniques, Phase Diagrams (Fe-C, Al-Si, Pb-Sn, Al-Cu etc.), Phase transformations in metals, Solidification in metals and alloys, Diffusion in solids, Mechanical working of metals, Strengthening mechanisms in metals, Mechanical properties of materials, Failure in materials, Non-destructive testing of materials, Composite materials, Corrosion of materials, Electrical properties of materials, Magnetic properties of materials, Thermal properties of materials, Optical properties of materials, Recycling of materials.

Texts / Reference Books:

1. William D. Callister, *Jr.Materials Science and Engineering*
2. V. Raghavan, Materials Science and Engineering: A First Course

Subject Code: ML6L007	Name: Structure of Materials and X-ray Diffraction.	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Production and detection of X-rays; Crystallography: lattice, motif, unit cells and crystal structures, symmetry elements, point groups, space groups, defects; Diffraction: Wave theory and electromagnetic waves, single crystal diffraction method and applications, powder diffraction method and applications, indexing of powder diffraction patterns, Bragg's law and Laue equation, reciprocal space and its application; Fourier transforms: analysis of diffraction patterns, structure factor and pair distribution function; Determination of crystal structures from symmetry and geometry; Rietveld method and precise crystal structures; Qualitative and quantitative phase identification.

Texts / Reference Books:

1. B. E. Warren, X-Ray Diffraction.
2. B. D. Cullity, S.R. Stock, Elements of X-ray diffraction.
3. Buerger, Martin J, Elementary Crystallography: An Introduction to the Fundamental Geometrical Features of Crystals.
4. F. C. Phillips, An Introduction to Crystallography.
5. Norman ,F. M., and Kathleen Lonsdale, International Tables for X-Ray Crystallography. Vol. 1
6. International Tables for Crystallography/ Volumes A(2006) / A1(2011) / B(2010) / C(2006)/ D(2006) / E(2010) / F(2012) / G(2006).

Subject Code:ML6L008	Name: Material Recycling and Waste Management.	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			
Recycling of different classes of materials, Solid Waste Regulations, Waste generation, Waste characterization, Physical properties of Waste, Waste separation and processing, Composting, Landfills, Incineration. **Texts / Reference Books:** 1. T. Randall Curlee, Sujit Das, William Andrew; 1 edition, *Materials recycling and waste management.*			

Subject Code: ML6L009	Name: Advanced Physical Metallurgy	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			
Microstructure & Properties: solidification and solidification structures, interfaces, crystallographic texture, residual stress, structure-property relations. Plasticity and work-hardening: fundamentals, stress-strain behavior, fracture, creep & deformation mechanisms. Recovery, recrystallization, grain growth. Phase transformation: thermodynamic basics, nucleation and growth, spinodal decomposition, martensitic transformations. **Texts / Reference Books:** 1. R. E. Smallman PhD and A.H.W. Ngan, *Physical Metallurgy and Advanced Materials, Seventh* Edition.			

Subject Code: ML6L010	Name: Materials Design	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			
Physical properties of materials – review; Property measurement techniques and limitations; Ashby diagrams – interpretations; Materials selection for: stiffness-limited design, strength limited design, fracture-limited design; Creep behavior of materials: design of materials for high temperature; Materials processing: classification and choice for design; Phase prediction using first-principles and CALPHAD approach; Structure-property relationship using molecular dynamics simulation; Processing – microstructure correlation using finite element and phase field simulation methods. **Texts / Reference Books:**			

1. M. Ashby, H. Shercliff & D. Cebon, *Materials Engineering, Science, Processing and Design*. Sidney Yip, *Handbook of Materials Modeling (Vol. 1 & 2).*
2. *ASM Handbooks Vol. 22A.*

Subject Code: ML6L011	**Name: Ceramic Materials**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): None

Introduction, Ceramic Materials: structure, microscructure and polymorphism, synthesis of ceramics, ceramic forming processes, silicate and non-silicate ceramics, structural, functional (electronic, optical) and bio-ceramics, nano-ceramics, Properties and Applications of Ceramics: refractory materials, properties of refractories, fracture of refractories, corrosion of refractories, different refractory lines, alumina-silica brick, magnesia refractories, silica brick, doloma refractories, carbonaceous refractories, spinel-containing refractories, glass tank blocks, ceramic wool preparation and properties, carbide and nitride based refractories, refractory coatings, refractory castables, unshaped refractory products, surface chemistry as a tool for the development of advanced refractory castables, thermo-mechanical considerations for refractory linings, refractory applications in refineries and circulating fluid bed reactors, heating wall refractories, damage and causes of failure, testing of refractory materials, refractory lining design and manufacture.

Texts / Reference Books:
W. D. Kingery, H. K. Bowen, Donald R. Uhlmann, *Introduction to Ceramics*, 2nd Edition.

Subject Code: ML6L012	**Name: Biomaterials Processing and Applications**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): None

Surface chemistry and physics of selected metals, polymers, and ceramics, surface characterization methodology, modification of biomaterials' surfaces, biosensors and microarrays, bulk properties of implants, acute and chronic responses to implanted biomaterials, drug delivery and tissue engineering; Property requirement of biomaterials; Concept of biocompatibility; Cell-material interactions and foreign body response; Assessment of biocompatibility of biomaterials, important biometallic alloys; Ti-based, stainless steels, Co-Cr-Mo alloys; Bio-inert, bio-active and bio-resorbable ceramics; Processing and properties of different bio-ceramic materials with emphasize on hydroxyapatite; Synthesis of biocompatible coatings on structural implant materials; Microstructure and properties of glass ceramics; Biodegradable polymers; Design concept of developing new materials for bio-implant applications.

Texts / Reference Books:
1. *TeohSwee Hin Engineering Materials For Biomedical Applications (Biomaterials Engineering and Processing Series*

Subject Code: ML6L013	Name: Surface Engineering	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Introduction to surface, Thermodynamics of surface, Surface dependent properties-physical, chemical and mechanical; Surface dependent degradation and their characteristics, Analysis of surface initiated degradation; Approaches and classifications of surface engineering techniques; Introduction to surface cleaning techniques by physical, mechanical and chemical routes; Surface modifications techniques-conventional surface modification methods applicable to steel, cast iron, and non-ferrous metals/alloys-shot peening, sand blasting, flame, induction hardening, solid state diffusion assisted surface modifications; Emerging surface modification techniques- chemical route (electroless deposition, sol-gel coating), electro-chemical routes (electro-deposition, electro-phoretic deposition); Chemical conversion coatings - hot dipping, thermal spraying; Surface painting- basic paint technology, polymeric binders, pigments and extenders, additives, essential concepts of paint formulation and paint properties, paint preparation (pigment dispersion), surface preparation and paint application techniques applied for film preparation and their properties; Surfaces in vacuum- ultra-high vacuum techniques and processes; Thin film technologies-development of metallic and ceramic thin film by physical routes (thermal evaporation, sputtering and ion implantation) and chemical route (chemical vapor deposition); Directed energy beam assisted surface engineering techniques (ion, electron beam and laser assisted surface engineering techniques), Economics and designing of surface engineering processes; Characterisation of surfaces, effect of substrate surface structure on the over-layer properties, theoretical and experimental evaluation of surface energies, solid-liquid and solid-gas interfaces, damage of the surfaces by corrosion and wear.

Texts / Reference Books:

1. M. Ashby, H. Shercliff& D. Cebon, *Materials Engineering, Science, Processing and Design*.
2. ,D. SrinivasaRao, Shrikant V. Joshi , *Daya Publishing House (2010)* .
3. W. Gissler, H.A. Jehn, Springer, *Advanced Techniques for Surface Engineering*.
4. Research Papers.

Subject Code: ML6L014	Name: Powder Materials and Processing	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Introduction: development of powder metallurgy, scope of powder metallurgy, characterization of metal powders, physical properties-particle size and shape determination, technological properties-apparent density, flow rate etc. and chemical properties, particle interaction and control; Powder manufacturing: powder mixing and blending, dry and colloidal processing, reduction, electrolysis, and atomization processes, shaping techniques such as compacting, injection molding; Compaction and sintering: die compaction and other consolidation techniques, sintering, sintering with liquid phase;

Powder metallurgy products: bearing, filters, friction parts, hard metals, refractory metals, contact materials, magnetic materials, structural parts, and dispersion strengthened materials.

Texts / Reference Books:

1. Glaus G. Goetzel, *TREATISE ON POWDER METALLURGY in three volumes*
2. *Volume 1: Technology of Metal Powders and Their Products*
3. *Volume II: Applied and Physical Powder Metallurgy*
4. *Volume III: Classified and Annotated Bibliography*

Subject Code: ML6L015	**Name: Heat Treatment of Materials**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): None

Heat Treatment -IT and CCT diagrams in steels, quench hardening and tempering of martensite, hardenability of steels, surface hardening processes, tool steels and their heat treatments, heat treatment of aluminium alloys, magnesium alloys, Ni-base super alloys and Ti alloys, Thermo-mechanical treatments; Hardenability, thermo-chemical and thermo-mechanical and thermo cycling treatments; Failure analysis of heat treated products.

Texts / Reference Books:

Gregory J. Bonami, *Heat Treatment: Theory, Techniques, and Applications (Materials Science and Technologies).*

Subject Code: ML6L016	**Name: Extractive metallurgy**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): None

Thermodynamics and kinetics of metallurgical reactions, heat transfer and fluid flow, Methods of extraction and refining of metals – pyrometallurgy, hydrometallurgy and electrometallurgy; Extraction of non-ferrous metals such as – U, Th, Cu, Zn, Au, Ag, Al, Pb, etc; Extractive metallurgy of rare earths; Iron making, blast furnace, blast furnace slag, various zones in blast furnace, controlling of various elements like P, Si, Mn, S, in hot metal, alternative routes of iron making processes *i.e.* solid state reduction, steel making principles, furnaces, modern steel making process, control of various elements in steel by refining the hot metal, slag property, stainless steel making, Ferro-alloy; Green extraction processes; Current research developments in extraction processes.

Texts / Reference Books:

1. Ghosh, H. S. Ray, *New Age International,Principles of Extractive Metallurgy*.
2. H.S Ray, R Shridhar, K.P Abraham , *East-West Private Ltd,Extraction of Non-Ferrous Metals*.
3. A. Ghosh, A. Chatterjee, *PHI Learning Ltd.,Iron making and Steel Making; Theory and Practice.*

Subject Code: ML6L017	Name: Mineral Beneficiation	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Principles of mineral beneficiation, Mineralogy, Colloids and material chemistry Sampling methodology, Working principles and equipment design for: primary crushers, secondary crushers, grinding, froth flotation, magnetic separation, electrical separation, Electro and Hydro-Metallurgy processes, Bio-mineral processing, Discrete element method simulations.

Texts / Reference Books:

1. Ghosh, H. S. Ray, *New Age International,Principles of Extractive Metallurgy*.
2. H.S Ray, R Shridhar, K.P Abraham , *East-West Private Ltd,Extraction of Non-Ferrous Metals.*
3. Barry A. Wills, Elsevier and Butterwoth – Heineman, *Wills' Mineral Processing Technology, Seventh Edition: An Introduction to the Practical Aspects of OreTreatment and Mineral Recovery.*

Subject Code: ML6L018	Name: Principles of Materials Engineering	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Introduction: Solid Engineering Materials- their classification and characteristic properties. Structure of solids: crystal systems/lattices, crystal structure, crystallographic planes and directions, interstitial sites, crystalline metals, ceramics, semiconductors and polymers. Microstructures and metallography; Amorphous or glassy state; Solidification of pure metal: homogeneous and heterogeneous nucleation processes, cooling curve, concept of supercooling, microstructure of pure metals. Defects in solids: point, line, planar and volume defects. Fundamentals of plastic deformation of metals, deformation by slip and twin, plastic deformation in polycrystalline metals, concept of cold working, preferred orientation; Annealing: recovery, recrystallization and grain growth; hot working; Properties of materials: Definition, units and common tests conducted to evaluate important engineering properties like physical, mechanical, chemical, electrical, magnetic, semi/super-conducting, optical, and thermal properties in engineering materials; Concept of formation of alloys: Types of alloys, solid solutions, factors affecting solid solubility, order-disorder transformation; Binary phase diagrams: isomorphous, eutectic, peritectic, eutectoid and peritectoid systems, effect of non-equilibrium cooling: coring and homogenization; Iron-cementite phase diagram: Construction and interpretation of Fe-Fe3C and Fe-Graphite diagrams. Microstructure, and properties of different alloys in steel and cast iron, types of cast iron, their microstructures and typical uses; Heat treatment: T-T-T and C-C-T diagrams, concept of heat treatments of steel: annealing, normalizing, hardening and tempering; microstructural effects brought about by these processes and their influence on mechanical properties. Effect of common alloying elements in steel, concept of hardenability, factors affecting it; Common alloy steels, stainless steel, tool steel, high speed steel, high strength low alloy steel, micro-alloyed steel, specifications of steels; Physical metallurgy of common non-ferrous alloys: Cu-,Al- and Ni- based alloys.

Microstructures and heat treatment of common alloys of these systems; Engineering ceramics and polymers: Structure, properties and application of common engineering ceramics and polymers.

Texts / Reference Books:

1. William D. Callister, *Jr.Materials Science and Engineering*, Wiley India (P) Ltd.
2. V.Raghavan, Materials Science and Engineering: *A First Course 5th Ed, Prentice Hall of India*, New Delhi (2000).
3. Sidney H. Avner, *Introduction to Physical Metallurgy*, Tata McGraw-Hill.
4. Butterworth-Heinemann, Michael Ashby, Hugh Shercliff and David Cebon, *Materials Engineering, Science, Processing and Design*

Subject Code: ML6L019	**Name: Mechanical Behaviour of Materials**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): None

Elasticity basics: Stress and strain tensors, tensor transformations, Mohr's circle representation of stress and strain, constitutive equations. Origin of stresses in thin films: thermo-elastic mismatch between film and substrate, lattice mismatch in hetero-epitaxial films, recrystallization, phase transformation, incorporation of atoms and chemical reactions. Application of the above for designing structures with low stresses. Experimental techniques for measuring stresses/strains in thin films: Substrate curvature; Stoney's equation, methods for curvature measurement and X-ray diffraction. Measurement of mechanical properties of thin films - nanoindentation, bulge test, 4-point bend test, and micro-tensile test. Models for high stresses, strain-hardening rates and Bauschinger effect in thin films, influence of grain size, film thickness and interfaces.

Texts / Reference Books:

1. Marc André Meyers, Krishan Kumar Chawla, Cambridge,*Mechanical Behavior of Materials*

Subject Code: ML6L020	**Name: Transport Phenomena**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): None

Heat, mass and momentum balance, laminar, turbulent flow, concept of boundary layer, friction factor, heat and mass transfer coefficients and dimensionless correlations; Process
modeling: governing equations, boundary conditions, and some case studies of some
important metallurgical system: packed and fluidized bed, moving boundary problems with melting, solidifications and reactions, solid-gas reactions. Modeling of electrochemical processes. Numerical methods applied in transport modeling: control volume method for solving partial differential equations. Numerical solutions of some metallurgical processes: extraction processes, iron making, steel making gas stirred ladle, filling ladle, fusion welding, cored wire injection, soaking pits, continuous casting etc.

Texts / Reference Books:

2. R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot. *Wiley International edition,Transport Phenomena.*
3. D. R. Poirier, G. H. Geiger, Wiley, *Transport Phenomena in Materials Processing*.
4. Julian Szekely, Academic Press, *University of Michigan,Fluid flow phenomena in metals processing.*

Subject Code: ML6L021	**Name: Corrosion Science and Engineering**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): None

Importance of corrosion, corrosion rates evaluation, thermodynamics of corrosion; Electrochemical mechanisms: Electrode potentials and corrosion tendency, polarization, mixed potential theory, Evan's corrosion diagrams, potential-pH diagrams; Different forms of corrosion including microscopic and macroscopic forms. High temperature corrosion: Oxidation laws, selective oxidation, internal oxidation and catastrophic oxidation. Corrosion testing: design principles of corrosion evaluation of materials, accelerated corrosion tests, common experimental techniques for corrosion rate measurements including electrochemical methods. Different forms of corrosion and their control *viz.*, uniform corrosion, galvanic corrosion, selective leaching, crevice corrosion, fill form corrosion, pitting corrosion, inter-granular corrosion, erosion corrosion, fretting damage, stress corrosion cracking, corrosion fatigue, hydrogen embrittlement and microbes induced corrosion. Elementary treatment of corrosion testing procedures, inhibitors and corrosion of steels. Corrosion protection methods -studies on electroplating, cathodic and anodic protection, protecting coatings, coatings for prevention of high temperature oxidation etc. Some case studies of real life corrosion.

Texts / Reference Books:

1. M.G. Fontana, McGraw Hill, Singapore, 1987, *Corrosion Engineering*.
2. Edward Arnold, London, 1983.A.S. Khanna, *Introduction to Oxidation of Metals*.
3. Zaki Ahmed, Butterworth-Heinemann Publication, *Principles of Corrosion Engineering and Corrosion Control.*

Subject Code: ML6L022	**Name: Diffusion in Solids**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s):None

Introduction; review of basic concepts, Ficks laws; measurement of diffusion coefficients;
formation of defects, movement of defects, random walk; fundamental thermodynamic relations; atomistic of diffusion, mechanism, effect of pressure, temperature and various driving forces on diffusion, uphill diffusion, Kirkendall effect, Darken's analysis; grain boundary and surface diffusion; diffusion along moving boundaries; applications, theories of creep and design of creep resistant alloys, prediction of creep life; diffusion theory of sintering, carburizing, nitriding and metalizing; tracer diffusivity, vacancy wind effect; ternary and multicomponent diffusion.

Texts / Reference Books:
1. Paul G. Shewmon, Paul G. Shewmon

Subject Code: ML6L023	Name: Advanced Joining Processes	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Welding standards and codes; Friction welding: process technology, effect of intermetallic and low melting phase formation; Diffusion bonding: mechanism of bond formation; Ultrasonic welding: thermo-mechanical process modeling, mechanism of bond formation; Friction stir welding and friction stir spot welding: thermo-mechanical and microstructure evolution modeling, multi-scale modeling scope, friction stir tool design; Dis-similar metal welding; Lead-free solders in electronic packaging technology: microstructure and mechanical properties.

Texts / Reference Books:
1. ASM Handbooks Vol. 6A.
2. Eds. R.S. Mishra, M.W. Mahoney, ASM, *Friction stir welding and processing*.
3. AWS codes and standards.

Subject Code: ML6L024	Name: Granular Materials	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Granular materials: the fourth state of matter, industrial importance, granular statics and flow, antiparticle forces, discrete and continuum models, balance laws, fluid–particle interaction, yield conditions, shear stress, yield surfaces, flow rules, equation for plane flow, theory for steady and plane flow, effect of wall roughness, exit condition, smooth wall and radial gravity problem for compressible flow, constitutive equations involving a yield condition for slow three-dimensional flow, constitutive equations that do not involve a yield condition, introduction to rapid flow: theory for rapid flow of smooth, inelastic particles, model for inelastic collisions, thermodynamic description of rapid granular flows, kinetic theory for a granular gas of smooth inelastic particles.

Texts / Reference Books:
1. K. KesavaRao and Prabhu R Nott, *An introduction to granular flows*

Subject Code: ML6L025	Name: Advanced Composites	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Synthesis of composites, reinforcements, matrices; Metal Matrix Composites (MMCs), Ceramic Matrix Composites (CMCs), Special High Temperature High performance Carbon-Carbon composites; Processing issues in Metal Matrix Composites and Ceramic Matrix Composites, Solidification, Particulate technology, Sol gel, Chemical Vapour Deposition (CVD) and Physical Vapour Deposition (PVD) routes of manufacturing composites; Physico-chemical aspects of interfaces in composites; Nan composites.

Texts / Reference Books:

1. Krishan Kumar Chawla, *Composite Materials: Science and Engineering*.
2. Krishan Kumar Chawla, *Ceramic Matrix Composites*.

Subject Code: ML6L035	**Name: Functional Oxides: Structure and Properties**	**L-T-P: 3-0-0**	**Credit:3**

Pre-Requisite(s): None

Introduction: Importance of oxides in functional applications, Revision of basic crystallography: point group and space group. **Structure:** Concepts of ionic bonding, Grouping of ions and structure rules, Radius ratio concept, Structure of crystalline oxides, Case studies, Demonstration of open-source software package(s) for geometric construction of oxide structures and determination of structural parameters. **Defect Reactions and Defect Equilibria:** Different types of defects in oxides, Rules for defect reaction, Kröger-Vink notations, Conditions of equilibrium, Thermodynamics, Conditions of stoichiometry. **Electrical conductivity and Conducting oxides:** Laws of diffusion,Lattice, grain boundary and surface diffusion, Theory of ionic conductivity, Solid electrolytes and fast ion conductors, Concepts of Thermoelectric effect. **Linear and non-linear dielectric oxides:** Theory of linear dielectrics, circuit description, Dielectric constant and polarization, Dipolar polarization theory, Crystallographic consideration towards non-linear dielectric behavior. Concepts of piezo and ferroelectricity, Case studies. **Magnetic Oxides:** Basic Theory, Types of magnetism, Exchange interactions, Case studies, Coupling of electrical and magnetic orders in oxides.

Texts and References:

1. L.L. Hench and J. K. West, Principles of Electronic Ceramics, John Wiley and Sons Ltd, New York, 1990.
2. W. D. Kingery, H. K. Bowen (Author), Donald R. Uhlmann, Introduction to Ceramics, Wiley-Interscience; 2nd edition, 1976
3. M. W. Barsoum, Fundamentals of Ceramics, CRC Press, 2002
4. Per Kofstad, Non-stoichiometry, Diffusion and Electrical Conductivity in Binary Metal Oxides, Wiley-Interscience, 1972