National Institute of Foundry & Forge Technology

Hatia, Ranchi - 834 003 (Jharkhand)

Course Structure and Syllabi for

B. Tech.

(Metallurgy & Materials Engineering)

Telephone:-0651-2290859,

Website:-www.nifft.ac.in

B. .Tech, Metallurgy and Materials Engg, <u>Proposed Course structure</u>

Semester- I

Sl.No.	Course code	Subject	L	T	P	Credits
1.	MT101	Math-I	3	1	0	4
2.	MT102	Chemistry	3	0	2	4
3.	MT103	Physics	3	0	2	4
4.	MT104	Engg.Mechanics	3	1	0	4
5.	MT105	Principle of Electrical Engg.	3	0	2	4
6.	MT106	English for Professional Communications	3	1	0	4
7.	MT107	Engg. Graphics-I	1	0	2*2	3
8.	MT108	Workshop Practice-I	0	0	2	1
9.	MT109	EAA (NCC/ NSS/ PT)	0	0	2	1
						29

Semester- II

Sl.no	Course code	Subject	L	T	P	Credits
1.	MT201	Materials Science& Engg.	3	1	0	4
2.	MT202	Fuels,furnaces & Refractories	3	0	2	4
3.	MT203	Math-II	3	1	0	4
4.	MT204	Solid Mechanics	3	1	2	5
5.	MT205	Basic Electronics .	3	0	2	4
6.	MT207	Engg.Graphics-II	1	0	2*2	3
7.	MT208	Workshop practice –II	0	0	2	1
8.	MT209	EAA (NCC/ NSS/ PT)	0	0	2	1
						26

Semester-III

Sl.no	Course code	Subject	L	T	P	Credits
1.	MT301	Math-III	3	1	0	4
2.	MT302	Fluid Mechanics	3	1	2	5
3.	MT303	Mineral Dressing	3	0	2	4
4.	MT304	Introduction to Computer Programming	3	0	2	4
5.	MT305	Thermodynamics& kinetics	3	1	0	4
6.	MT306	Principle of Extractive Metallurgy	3	0	2	4
						25

Semester-IV

Sl.no	Course code	Subject	L	T	P	Credits
1.	MT401	Numerical Methods& its applications	3	0	2	4
2	MT402	Heat and Mass Transfer	3	1	0	4
3.	MT403	Phase equilibria in Materials system	3	1	0	4
4.	MT404	Iron Making	3	1	0	4
5.	MT405	Physical Metallurgy-I	3	0	2	4
6.	MT406	Mechanical behavior of Materials	3	1	0	4
						24

Semester-V

Sl.no.	Course code	Subject	L	T	P	Credits
1.	MT501	Steel Making	3	1	0	4
2.	MT502	Physical Metallurgy-II	3	1	0	4
3.	MT503	Engg. Economics	3	1	0	4
4.	MT504	Foundry Technology	3	0	2	4
5.	MT505	Manufacturing Technology	3	0	2	4
6.	MT506	Mechanical properties of Materials and its evaluation	3	0	2	4
						24

Semester-VI

Sl.no	Course code	Subject	L	T	P	Credits
1.	MT601	Metal Forming Technology	3	0	2	4
2.	MT602	Corrosion Science and Engg.	3	0	2	4
3.	MT603	Extraction of Nonferrous Metals	3	1	0	4
4.	MT604	Heat Treatment Technology	3	0	2	4
5.	MT605	Elective-I	3-1-	0		4
6.	MT606	Characterization of Materials	3	0	2	4
						24

Minimum Four weeks of Industrial Training, If possible, Mini projects to be carried out in the Industry itself.

Elective-I

1. Physics of Metals (3-1-0)
2. Methoding of Casting(3-1-0)
3. Materials Handling (3-1-0)
4. Failure analysis (3-1-0)
5. Alternative routes of Iron and Steel making (3-1-0)
6. Ceramic Processing and Structural Ceramics (3-0-2)

Semester-VII

Sl.no	Course code	Subject	L	T	P	Credits
1.	MT701	Composite Materials	3	1	0	4
2.	MT702	Computer applications in Metallurgy	3	1	0	4
3.	MT703	Environment & Pollution control in Iron& Steel Industry	3	0	2	4
4.	MT704	Industrial Engg& Management	3	1	0	4
5.	MT705	Elective-II				4
6	MT706	Industrial Tour, Training & Report				2
7.	MT707	Comprehensive Viva Voce				2
						24

Elective –II

1. Electronic ,Optical & Magnetic Properties Of Materials (3-1-0)
2. Modern NDT (3-0-2)
3. Metal Joining (3-0-2)
4. Polymer Technology (3-1-0)
5. Instrumentation and Control (3-0-2)
6. Energy Conservation and Management in Iron and Steel Industry (3-1-0)

Semester-VIII

Sl. No.	Course code	Subject	L	T	P	Credits
1.	MT801	Org. behavior& Industrial psychology	3	1	0	4
2.	MT802	Total Quality Management	3	0	0	3
3.	MT803	Advanced Materials	3	0	0	3
4.	MT804	Elective- III				4
5.	MT805	Project work & viva voce				8
6.	MT806	Seminar presentation				2
						24

Electives -III

1. Secondary steel making (3-1-0)
2. X- Ray crystallography (3-1-0)
3. Forging Die design (3-1-0)
4. Selection of Engg. Materials (3-1-0)
5. Nano Materials and Its Applications (3-1-0)

Total 200 Credits

Annexure-A (b)

B. Tech, Metallurgy and Materials Engineering, Syllabus
I SEMESTER

MT 101 Mathematics- I: L-T-P-C (3-1-0-4)

Matrices: Definitions, Addition and Multiplication, Square Matrices of different types, Determinants, Adjoint and Inverse of a Matrix, Elementary transformation, Rank, Normal form, Solution of line equations, Solvability, Matrix algebra, Cayley- Hamilton theorem, Eigen values and Eigen functions.

Co ordinate geometry of two dimensions: Co-ordinate systems, Projections and directions, Plane, Straight line, Sphere, Cylinder, Cone and Conicoids.

Vector analysis (with geometrical interpretation and applications): Elementary discussion, Product of two or more vectors, Geometry of Line, Plane and sphere in terms of vectors.

Differential Calculus: Continuity and differentiability, Differentiation, Successive differentiation, Expansion of function remainders, Intermediate forms, Partial differentiation, Total differential coefficients, Approximate calculations, Jacobians, Reduction of Laplacian operator in different co ordinate systems.

Introduction to differential equations.

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MT102 Chemistry: L-T-P-C (3-0-2-4)

Chemistry of engineering materials with particular reference to metals, alloys, ceramics and glasses, Introduction to water treatment techniques.

Electrochemistry: Electrochemical reactions, Electrochemical cells, laws of electrolysis, Conductance, Electroplating, Electroanalytical methods of chemical analysis, such as conductometry, potentiometry, and polarography.

Thermochemistry: Heat of combustion, Heat of formation, Hess's law of heat of summation, heat of neutralization, Calorimetry.

Polymers: Classification of polymers, properties of polymers, methods of polymerization, common polymer resins such as phenolic resin, amine resin, alkyd resin, polyesters, epoxy resin, polyurethane and furan polymers.

Spectroscopy: Emission and absorption spectroscopy, origin of spectra, principles, methods of chemical analysis based on spectroscopy such as atomic and molecular absorption.

MT103 Physics: L-T-P-C (3-0-2-4)

Nature of waves and particles, Wave packets and uncertainty, Wave particle duality, Wave mechanics and its mathematical tools, Classical and quantum statistics, Statistics of discrete energy levels, Black body spectral density, Bose condensation, Free electrons, Density of states, Kronig- Penny model, Effective mass, Band structure, Electrons in various types of solids, Particle in quantum well, Harmonic oscillator, Application to semiconductor doping, Non periodic materials, Tunneling of particles and examples, Tunneling through multiple barriers, and semi conductor junctions; Interactions among quantum wells, materials under electric and magnetic fields, magnetic resonance effects;

Nano structures: Concept of electrons in low dimensional confinement, Quantum wells and Superlattices leading to new device concepts. Lasers: Einstein coefficients, Population inversion, Light amplification, Optical resonators, Characteristics of lasers; Superconductors.

MT104 Engineering Mechanics: L-T-P-C (3-1-0-4)

Introduction: Fundamental concepts and principles, Introduction to SI units, Review of vector algebra, Important vector quantities.
Statics of particles: Concept of Force, Resultant of Forces, Resolution of Forces, Equilibrium of particles.
Statics of rigid bodies: Definition of rigid bodies, Dot product and cross product, product of two vectors, mixed triple product of three products, Moment and couple, Varignon's theorem, Equivalent system of forces, simplest resultants, Equilibrium of rigid bodies.
Analysis of structures: determination of forces in members of plane trusses by methods of joints and sections.
Friction: Laws of dry friction, wedges, square threaded power screws, belt friction.
Properties of Surface: Centriods and centre of gravity of areas and lines, volumes, Theorems of Pappus- Guldinus, Second moment of inertia of an area, Polar moment of inertia, parallel axis theorem.
Kinematics of particles: Position, Velocity and acceleration of a particle in rectilinear and curvilinear motion, Relative motion, Motion of projectiles, Tangential and normal components of acceleration.
Kinetics of particles: Newton's second law of motion, Equation of motion, Dynamic equilibrium.
Kinematics of rigid bodies: Introduction, Translation, Rotation about a fixed axis, General plane motion, Absolute and relative velocity in plane motion, Plane motion of a particle relative to a rotating frame- Corriolis acceleration, Motion about a fixed point, General motion.

MT105 Principles of electrical engineering: L-T-P-C (3-0-2-4)

DC Circuits: Circuit elements and their characteristics, Circuit analysis using KCL, KVL, Solution of Mesh and Nodal equations of R-L-C networks, Circuit theorems- Superposition, Thevinin, Norton, Maximum power transfer and Reciprocity theorem.
AC circuits analysis: Periodic wave form, Peak, Average, RMS, Form factor of AC quantity, RLC circuits with sinusoidal excitation, Phase notation, Reactance and Impedance, Series and Parallel Resonance.
Poly phase circuits: Three phase system, Star- Delta connected sources and loads, 3- wire and 4- wire system, Phaser diagram, Balanced and unbalanced systems line and phase values, Power measurement.
Magnetic circuits: Definition of magnetic quantities, Concepts of magnetic and electrical analogy, B-H Curve, Cyclic Magnetization, Leakage, Hysteresis and Fringing, Core losses.
Electromagnetic Induction: Faraday's Law, Dynamic Induction, Fleming's RHR and LHR, Self and Mutual Induction, Lenz's Law, Coupling coefficients

Reference Books:

1. Kothari D.P. and Nagrath I.J., Electrical Machines, Tata McGraw Hill.
2. Huges E., Electrical Technology, Orient Longman.
3. Cottan H., Advanced Electrical Technology, ISSAC Pitman & Sons.
4. Vincent D. T., Electrical Engineering Fundamentals, PHI.

MT106 English for professional communication: **L-T-P-C (3-1-0-4)**

Communication: Its role, process, barriers, dealing with barriers, psychology insights into communication, Role of personality- personality types, transactional analysis.
Verbal skills: Sound pattern, phonetics, pronunciation, modulation, stress, elision, vocal qualifiers, rhythm, vocal segregates, characteristics and sound patterns.
Non verbal skills: Paralanguage, gestures, prescenics, Kinesics
Listening skills: Types and techniques of developing it
Presentation skills: Making presentation, audio video use (visual aids), the role of PLAN in presentation, characteristics of good speech and presentation.
Written skills: Fundamentals of English grammars, Usage, Editing, Effective writing, drafting, proposals, report, official letter writing, use of positive and negative language, persuasive letters, orders, messages, Style- concise, precision and vocabulary, Use of language for specific goal/ audience/reader.

MT107 Engineering Graphics- I: L-T-P-C (1-0-2*2-3)

Introduction: Importance of engineering drawing, Drawing instruments and uses, BIS specifications, Layout of drawing sheets, Lines, lettering and dimensioning.
Conic sections: Ellipse, Parabola and Hyperbola
Curves: Cycloid, Epicycloid, Involutes, Spirals and helices
Projections: Theory of projections, Orthographic projections, projection of points and straight lines.
Projection of solids: Intersection between prisms, cylinder and cone combinations with axes in the same plane.
Development of Surfaces: Parallel line, Radial line, Triangulation and approximate development methods of surfaces of solids.
Pictorial projections: Isometric projections and Isometric views of solids and combination of solids, perspective projections of solids and combination of solids using visual ray method and vanishing point method.
Sections of solids: Section planes, projections of solids with section planes parallel, perpendicular and inclined to reference planes. True shape of sections.
Computer aided drafting: Introduction to computer aided drafting.

MT108 Workshop practice- I: L-T-P-C (0-0-2-1)

Machining of wood and plastic materials, Fitting, Smithy, tools and processes. Selected exercise in carpentry, fitting and hand forging. Use of measuring tools, instruments and gauges.

II SEMESTER

MT201 Materials Science and Engineering: L-T-P-C (3-1-0-4)

Introduction, Classification of Engineering Materials and Their Applications, Structure-property Relationship.
Bonding in solids- Ionic, covalent and metallic bonding, solid solutions, substitutional and interstitial solid solutions, Hume Rothery rules, Intermetallic compounds, normal valency compounds, electron compounds, interstitial compounds.

Conductors, Theory of Conduction; Semiconductors, Band Theory, Zone Theory; Insulators, Theory of Polarization; Magnetic Materials, Ferrimagnetism, Magnetic Domain Theory.
Non Crystalline and Semi crystalline Materials: The Glass Transition Temperature, Viscous Deformation, Structure and Properties of Glasses, Ionic Glasses, Covalent Glasses, Metallic Glasses.
Structure and Properties of amorphous and semi crystalline polymers, Polymer Conformation and Configurations, Factors determining Crystallinity of Polymers, Semicrystalline Polymers.
Structure and Properties of Rubbers and Elastomers, Thermoset and thermoplastic Elastomers, Crystallization of Elastomers.

Reference Books:

1. Raghavan V., Materials Science & Engineering, PHI.
2. Wulff Series, Vol. 4, Electronic Properties, Wiley.
3. Reed Hill R.E., Physical Metallurgy Principles, Affiliated East West Press.
4. Callister W., Materials Science and Engineering, John Wiley & Sons.

MT202 Fuels, Furnaces and Refractories: **L-T-P-C (3-0-2-4)**

Fuels: Classification, Their merits and limitations
Solid Fuels- Origin of coal, its types, properties, proximate and ultimate analysis, Storage and reserve in India. Coal Washing, Preparation and blending methods, application of coal.
Coke making by beehive and byproduct ovens. Modern practices of coke making, Principles of graphitization and reactivity. Characterization of coke and coal. Selection of reductant fuel for BF, DRI, COREX, Cupola and Pit furnaces.
Liquid and gaseous fuels- Types and uses of liquid and gaseous fuels. Flame characteristics. Burners for liquid, gas and pulverized coal. Synthesis and reformation of gas for direct reduction. Producer and water gas.
Furnaces: Classification of Furnaces, Basic working principles of fuel fired, resistance, induction and arc furnaces. Energy conservation measures in furnaces. Advantages and disadvantages of various kind of furnaces.

Refractories: Classification of refractories, Properties and application of fireclay, silica, chromite, graphite, magnesite, dolomite, zirconia, silicon carbide, silimanite and kyanite refractories.

Reference Books:

1. Gupta O.P., Elements of Fuels, Furnaces and Refractories, Khanna Publishers.
2. Gilchrist J.D., Fuels, Furnaces and Refractories, Pregamon.
3. Nandi D.N., Handbook of Refractories, Tata McGraw-Hill.
4. Norton F.H., Refractories, McGraw-Hill.

MT203 Mathematics- II **L-T-P-C (3-1-0-4)**

Vector Calculas: Differentiation of vectors and their products, Differential operators, Gradient, Divergence, Curl in relation to scalars and vectors and their functions. Physical interpretations: Line and surface integrals, Gauss and Stokes theorems.
Complex analysis: Introduction, analytic functions, Cauchy- Riemann equations, Line integral, Cauchy integral theorem and formula; Taylor and Laurent series. Cauchy's residue theorem, single point, point at infinity, Liouville theorem, Jordan's Lemma. Evaluation of definite integrals, Bromwich contour integral, Branch points and contour integrals.
Algebra: Series- Tests of convergence and divergence of series, proof of tests, Convergence of infinite products.
Integral Calculus: Methods of integration, Integration of irrational algebraic and trigonometric functions, Reduction formulae, Definite integrals, Geometrical properties, Quadrature, Rectification, Volumes and surfaces, Differentiation and integration of integrals, Gamma and Beta functions, Multiple integrals with change of variable, Application of centre of gravity and moment of inertia.

MT204 Solid Mechanics: **L-T-P-C (3-1-2-5)**

Introduction: Types of loads, concepts of stress and strain, Normal and shearing stress, Stress- strain diagram, Hooke's Law, Deformation of axially loaded members, Statically indeterminate problems, Thermal stresses and strain, Deformation of compound bars, Lateral strain, Poisson's ratio, Generalized Hooke's law, Bulk modulus, Shearing strain, Elastic constants and their relationships.
Torsion: Theory of torsion, Deformation in a circular shaft, Statically indeterminate problems, Power transmission shafts.
Pure bending: Theory of simple bending, Deformation in a symmetric member in pure bending, Normal stresses due to bending of beams, Bending of composite beams.
Transverse Loading: Horizontal shear flow, Shearing stresses in beams, Shear stress, Distribution in common types of beams.
Shear Force and Bending Moment: Relation among loads, Shearing Force and Bending moment diagrams for cantilever, Simply supported and overhanging beams, Maximum bending moment and pouts of contra- flexure.

Transformation of Stress: Principal stress and their planes, Mohr's circle for plane stress, Combined loading.
Thin walled pressure vessels: Hoop and Longitudinal stresses in Thin cylindrical and spherical shells subjected to internal pressure, Changes in dimensions and volumes.
Columns: Bucking of columns due to axial loads, Euler's formula for column with different end conditions.

MT205 Basic Electronics: L-T-P-C (3-0-2-4)

Semiconductor Diode characteristics: Qualitative theory of p-n junction, p-n junction as a diode, Current components in a p-n diode, the volt- amp characteristics/ diode resistance, Breakdown diodes, Photo diodes, LEDs.
Transistor characteristics: The junction transistor, Transistor current components, transistor as an amplifier, Transistor construction, Detailed study of the current in a transistor, The transistor- alpha, the common base configuration, The common- emitter configuration, The common- collector configuration, Transistor biasing technique and thermal stabilization.
Field effect Transistor: Junction field effect transistor, pinch- off voltage, JFET volt-amp. Characteristics, The insulated gate FET (MOSFET), a generalized FET amplifier, biasing of FET, The FET as voltage- variable resistor (VVR)
Rectifier: Half wave rectifier, Ripple factor, Full wave rectifier, Full wave circuits, The bridge rectifier voltage- multiplier, Filters (L- filter, C- filter, L-C filter)
Untuned amplifiers: Classification of amplifiers, push- pull amplifiers, Class- A large signal amplifier, class- B and Class- AB and their operation, RC coupled amplifier, Low frequency response of an RC- coupled stage.
Feedback Amplifier and Oscillators: Feedback concept, General characteristics of negative feedback amplifiers, voltage series feedback, current shunt feedback, voltage shunt feedback, operational- amplifier, Basic uses of operational amplifier. Sinusoidal oscillators, the phase shift oscillators, Resonant- circuit oscillators, Crystal oscillators.
Digital Electronics: Number system, Boolean algebra, Universal logic gates, Realization, Karnaugh's map, Flip- Flop, Registers and Counters.

MT207 Engineering Graphics-II L-T-P-C (1-0-2*2-3)
Introduction to design process and drawings.
Conventions: Code of practice for engineering drawing- Methods of dimensioning- Representation of details like drilled and tapped holes, Counter- sunk and counter- bored holes etc.- Representation of standard components like bolts, nuts, washers etc.
Assembly concepts: Methods and concepts of assemblies- Assembly requirements- Methods of assembly using bolts, nuts, screws and pins- Methods of arresting motion of a member in a assembly.
Assembly drawing practice: Making free hand sketches of typical sub- assemblies, like flange couplings, stuffing box, journal bearings, rolling element bearings, keyed joints, Cotter joints, gears, belts, brackets and C- clamps. Detailed three view drawings of assemblies of (i) stop valve (ii) tail stock (iii) hydraulic cylinder and piston (iv) four speed gear box (v) universal joint (vi) cross head (vii) connecting rod (viii) Safety valve

(ix) machine vice and (x) screw jack. Assembly drawing with sectioning and bill of materials; Assembly and Disassembly, Detailed part drawings from assembly drawings.
Production drawings: Limits, fits and tolerances, dimensional and geometric tolerances, surface finish symbols. Computer aided design, and use of software packages for engineering drawings.

MT208 Workshop Practice- II **L-T-P-C (0-0-2-1)**

Metal casting, Welding, Sheet metal fabrication, and basic machining processes, Materials, tools and instruments used. Elementary exercises in molding, casting, gas and arc welding, sheet metal forming, turning, shaping and milling.

SEMESTER- III

MT301 Mathematics- III **L-T-P-C (3-1-0-4)**

Differential Equations: Definitions, Differential equation of first order, of first degree and higher, Singular solutions, Geometrical interpretations of differential equations, Linear equations of higher order with: constant coefficients and variable coefficients (Second order and homogeneous equations), Simultaneous differential equations of one or more variable, partial differential equations, total differential equations, geometrical interpretations, solution of Laplace equation, Heat conduction equation and wave equations by separation of variables in Cartesian, cylindrical and spherical polar co ordinate systems.
Special Functions: Solution of Legendre and Bessel differential equations, Different kinds of associated functions, Orthogonality conditions, Expansion of functions in terms of Legendre polynomials and Bessel functions.
Integral Transforms:
Definitions, Laplace transforms, Inverse Laplace transforms, Fourier series- Expansion, Conversion into different intervals, Fourier integral formula, Fourier Mellin theorem, Infinite and Finite Fourier Transforms and Hankel transforms. Definite integrals with the help of Transforms, Application of Transforms to the solution of boundary value problems. Heat and wave equations.

MT302 Fluid Mechanics: **L-T-P-C (3-1-2-5)**

Introduction: Definitions, Fluid properties, classification of fluids and flow regimes, Fluid statics: Stationary fluids and liquids subjected to constant linear acceleration and to constant rotation. Fluid kinematics: Lagrangian and Eulerian descriptions, Pathlines, Streaklines and streamlines, acceleration. Integral flow analysis: Reynolds transport theorem, conservation of mass/ continuity equation and conservation of linear and angular momentum for a control volume in inertial and accelerating reference frames, energy equation, Bernoulli's equation. Enginering applications, Differential analysis of flow: Continuity and Navier- Stokes equations. Dimensional analysis, Similitude theory. Inviscid flows: Irrotational flow, circulation, velocity potential and applications. Viscous

flows in pipes and ducts, External viscous flows: Concepts of boundary layer, Momentum integral equation, drag and lift, separation.

Reference Books:

1. Szekley J.S. & Themlis N.J., Rate Phenomena in Process metallurgy
2. Bird R.B., Stewart W.E. & Lightfoot J.F., Transport Phenomena.
3. Geiger G.H. & Priorer D.R., Transport Phenomena in Materials Processing, Addison Wesley.

MT303 Mineral Dressing: L-T-P-C (3-0-2-4)

Ores and Minerals: Rocks, Minerals, Ores and Gangue, Elementary ideas of formation of rocks and mineral deposits and their mode of occurrence associations. Scope of mineral processing.
Comminution and Liberation: Concept and importance of liberation. Theory and practice of crushing and grinding.
Sizing and classification: Laboratory sizing techniques, Interpretation and plotting of sizing data. Industrial screens and classifiers.
Concentration: Principles and applications of heavy media separation, Jigging, Flowing film concentration and equipments used. Physico chemical principles of Flotation, Flotation reagents, Machines and circuits, Electrostatic and magnetic separation. Pre concentration techniques.
Dewatering and Drying: Principles and practice of thickening, Filteration and Drying.
Flow sheets: Typical flow sheets for the beneficiation of Coal and ores of Cu, Pb, Zn, Iron, Al and Mn with special reference to Indian deposits.

Reference Books:

1. Wills B.A., Mineral Processing Technology, Pergamon.
2. Gaudin A.M., Principles of Mineral Dressing, Tata McGraw-Hill.
3. Pryor E.J. Mineral Processing, Allied Science.
4. Jain S.K., Ore Processing, Oxford & IBH.

MT304 Introduction to computer programming: L-T-P-C (3-0-2-4)

Introduction to computer systems: Representation of data in computers, Number systems.

C and C++ Language: Introduction, constants, variables and data types, operators and expressions, input/ output streams, decision making and pointers. Objects and Classes.
Introduction to JAWA and MATLAB.

MT305 Thermodynamics and Kinetics: L-T-P-C (3-1-0-4)

Basic concepts: Thermodynamic systems and processes, state and path functions, Extensive and Intensive properties, Internal Energy, First Law of Thermodynamics and

its applications in various metallurgical processes. Enthalpy, Heat capacity, Hess's Law, Kirchoff's Law, Second Law of Thermodynamics and Entropy. Entropy changes for various processes, Significance of sign change of entropy. Trouton's and Richard rules. Driving force of a chemical reaction, Combined statement of First and Second Law of Thermodynamics. Statistical concept of entropy.

Free Energy and its Significance: Helmoltz and Gibbs free energy, Free energy change as a function of temperature. Concepts of standard state, Fugacity, Activity and Equilibrium constants. Gibbs- Helmoltz equation, Van't Hoff equation, Le Chatelier principle, Clausius- Clapeyron equation, Maxwell equation.

Ellingham Diagram and its significance in metallurgical engineering., Third Law of Thermodynamics.

Solution Thermodynamics: Solution, Mixture and Compounds, Raoult's Law, Ideal, Non ideal and Regular solutions and their thermodynamic properties, Free energy of mixing, excess and integral quantities, Alpha function, Gibb's– Duhem equation and its integration. Dilute solutions, Henry's Law and Sivert's Law, Alternate standard states, Interaction coefficients.

Kinetics: Basic concepts of reaction steps, rate of reactions, Order of reaction, Determination of order of reactions. Arrhenius equation in reaction kinetics, Mechanism of reaction and rate controlling steps, Activated complex and its thermodynamic and kinetic aspects, Effect of concentration and temperature on reaction kinetics. Kinetics of heterogeneous reactions.

Reference Books:

1. Gaskell D.R., Introduction to Metallurgical Thermodynamics, McGraw-Hill.
2. Darken L.S. and Gurry R.W., Physical Chemistry of Metals, McGraw-Hill.
3. Upadhayaya G.S. and Dube R.K., Problems in Metallurgical Thermodynamics and Kinetics, Pergamon.
4. Szekely J and Themelis N.J., Rate Phenomena in Process Metallurgy, Addison Wesley.
5. Mohanty A.K., Rate Processes in Extractive Metallurgy, PHI.

MT306 Principles of Extractive Metallurgy: L-T-P-C (3-0-2-4)

Introduction: Scope of extractive Metallurgy, Occurrence of Metals in Nature, Minerals and Ores, Elementary concepts of extraction of Metals from their ores. Ellingham diagrams for oxides and sulphides.

Pyrometallurgy: Ore preparation, Calcination, Roasting, Predominance area diagram, Roasting practice, Reduction smelting, Matte smelting, Converting, Role of Slags.

Refining Methods: Fire refining, Liquation, Poling, Cupellation, Vacuum distillation, Zone refining, Electrolytic refining.

Hydrometallurgy: Ore preparation, Leaching practice, Bio leaching, Kinetics of leaching, Role of oxygen in leaching, Recovery of metals from leach liquor by solvent extraction, ion exchange, precipitation, cementation and electro winning methods.

Electrometallurgy: Theory of electrodeposition, Faraday's Laws, Electrode potential, EMF series, Nernst equation, Hydrogen over voltage, Electro winning, Pourbaix diagram.

Calculation of material and heat balances pertaining to some important metal extraction process.

Reference Books:

1. Newton J., Extractive Metallurgy, Wiley.
2. Gilchrist J.D., Extraction Metallurgy, Pergamon.
3. Rosenqvist T., Principles of Extractive Metallurgy, McGraw Hill.
4. Ray H.S. and Ghosh A., Principles of Extractive Metallurgy, New Age International.

SEMESTER IV

MT401 Numerical methods and its applications: L-T-P-C (3-0-2-4)

Errors in computation, instability, Non linear equation in one variable: Direct and Iterative methods, order of convergence, Iterative methods for systems of non linear equations. Linear system of equations, direct and iterative methods, rate of convergence of iterative methods, ill conditioedness of systems and condition numbers.
Interpolation: Lagrange, Newton divided difference formula, Newton's interpolations, errors in interpolation, Gauss, Stirling, Bassels, Splines.
Approximation: Least square and uniform approximations differentiation –differentiation using interpolation formulas
Integration: Integration using interpolation,
Newton-cotes formulas, Gauss quadrature rules. .
Ordinary Differential Eqation: Taylor, Euler and Runge- kutta formula, Multi step methods.
Computer implementation of various methods.

Reference Books:

1. Sastry S.S. Introductory Methods of Numerical Analysis.
2. Chapra S.C. and Canale R.P., Numerical Methods for Engineers, Tata McGraw Hill.
3. Hildebrand F.B., Introduction to Numerical Analysis, Tata McGraw Hill.

MT402 Heat and Mass Transfer: L-T-P-C (3-1-0-4)

Conduction: Mechanism, Fourier's general conduction equation in 3D; ID Steady state conduction with heat generation, Composite plane wall and cylinders, thermal resistance network, Critical thickness of insulation; extended surface heat transfer, 2D Steady state conduction , Solution for simple boundary condition, Unsteady heat conduction: lumped parameter system, semi infinite wall with convection boundary condition, Use of Heisler charts.

Convection: Review of hydrodynamics equation of boundary layer theory .Convection boundary layers: Velocity and thermal boundary layers. Laminar boundary layer analysis on flat plate. Fully developed heat transfer through smooth pipe, Relation between fluid friction and heat transfer .Turbulent boundary layer, Forced convection correlations. free convection, laminar free convection on a vertical flat plate, empirical correlations.
Boiling and Condensation:
Mechanism, different regimes of boiling, boiling curves and correlation, laminar film condensation on a vertical plate.
Heat exchangers: types, analysis, LMTD, effectiveness-NTU method.
Radiation: Physical mechanism, Radiation properties, Black body radiation, Gray body, Special dependence of radiation properties, Kirchoff's Law, Wein's displacement Law. View factor; Radiation exchange between infiniteplanes and between gray bodies; Radiation shielding; re- radiating surface and 3- surface enclosures, network representation.
Mass transfer: Fick's Law, Similarity with convection and correlations.

Reference Books:

1. Holman J.P., Heat Transfer.
2. Geankopolis C.J., Transport Process: Heat Mass & Momentum.
3. Welty J.R., Wicks C.E. & Wilson R.E., Fundamentals of Momentum, Heat & Mass Transfer.

MT403 Phase Equilibria in Materials system: L-T-P-C (3-1-0-4)

Introduction to thermodynamics of phase change: Equilibrium, phase stability ,evolution of phase diagrams, chemical potential gradient , Atomic model of diffusion, solid solution , Theories of alloying, Hume- Rothery rules, Single component systems, P-T diagrams, Allotropy.
Free energy- composition diagram, Binary equilibrium diagrams, Gibbs phase rule , Tie line, Lever rule, Isomorphous , eutectic, eutectoid, monotectic, peritectic, peritectoid, Syntectic systems. Common alloy systems, Ceramic systems.
Microstructure of plain carbon steels and cast irons.
Complex phase diagram: Rule for construction of phase diagrams for complex system. Metastability, computation of phase diagrams.
Ternary system: Ternary phase diagrams, representation, isothermal and vertical sections, Ternary isomorphous and eutectic systems, Tie lines, Gibb's triangle representation, Two phase, Three phase and four phase equilibrium, Experimental determination of phase diagrams. Microscopy, X-ray diffraction technique, Thermal analysis, Dilatometry, Electrical resistivity, Diffusion couples and Magnetic methods.

Reference Books:

1. Gordon P., Principles of Phase Diagrams in Materials Systems, McGraw Hill.
2. Prince A., Alloy Phase Equilibria, Elsevier.
3. Rhines F.N., Phase Diagrams in Metallurgy, McGraw Hill.

4. Hume- Rothery W., Christian J.W. and Pearson W.B., Metallurgical Equilibrium Diagrams, The Institute of Physics (London).

MT404 Iron Making: L-T-P-C (3-1-0-4)

Raw Materials and their properties: Iron ore, flux , Agglomerates and coke.
Preparation of ore: Sintering and palletizing, blast furnace burdening and distribution, testing of raw materials for B.F
Design: B.F profile , Stove and gas cleaning units, instrumentation , refractory used in B.F and stove
Reactions: Fe-C-O, Fe-O-H phase equilibrium, Reaction in stack, bosh and hearth, formation of primary slag , bosh slag and hearth slag . Slag composition and its control, Metal –slag reactions, control of hot metal composition
Process Control: Factors affective fuel consumption and productivity, Recent development in B.F Operations like, Bell-less top charging system, High top pressure, Humified and oxygen enrichment of B.F and auxilliary fuel injections through tuyers. Irregularitions in B.F Operations and their remedies. B.F Stoichiometry, mass and enthalpy balance, problems based on charge calculations.
Alternate routes of Iron Making: Processes of sponge iron production. Coal based and gas based. Smelting reduction processes.

Reference Books:

1. Biswas A.K., Principles of Blast Furnace Iron Making, SBA.
2. Tupkary R.H., Introduction to Modern Iron Making, Khanna Publishers
3. Gupta S.S. and Chatterjee A., Blast Furnace Iron Making, SBA New Delhi.
4. Chatterjee A., Singh R. and Pandey B., Metallics for Steel Making- Production and Use, Allied Publishers.

MT405 Physical Metallurgy- I: L-T-P-C (3-0-2-4)

Introduction, Crystal structure and crystal defects.

Metallography: Metallurgical microscope, Specimen preparation, Techniques for microscopic observation. High temperature microscopy, Quantitative metallography.

X- Ray crystallography: Fundamentals of crystallography, Reciprocal lattice, X- Ray diffraction, Bragg's Law. Lau, Powder and rotating crystal methods, Intensity calculations, Lorentz polarization, absorption, temperature, multiplicity factors. Application of x-ray diffraction to identification of Bravais lattices, calculation of lattice parameters, residual stresses and orientation determination.

Diffusion: Fick's first law of diffusion, self diffusion and interstitial diffusion in alloys, diffusion mechanisms, activation energy. Fick's second law of diffusion & its solution. Applications. Boltzaman- Matano analysis, kirkendall effect. Darken analysis.

Reference Books:

1. Reed Hill R.E., Physical Metallurgy Principles, Affiliated East West Press.
2. Azaroff L.A., Introduction to Solids, Tata McGraw Hill.
3. Barret C.S. & Massalski T.B., Structure of Metals, Pergamon.
4. Cullity B.D. Elements o0f X-Ray Diffraction, Addition-Wesley.
5. Smallman R.E. & Ashbee K.H.G., Modern Metallography, Pergamon.
6. Gifkins R.C., Optical Microscopy of Metals, Pitman.

MT406: Mechanical behavior of Materials: L-T-P-C (3-1-0-4)

Theory of elasticity and plasticity, Generilised Hooke`s law, stress-strain relationship. Mechanism and crystallograply of slip and twinning. Concept of critical resolved shear stress. Deformation of single crystals and polycrystals. Hall –Petch relationship.

Dislocation Theory: Type of dislocations, Their geometrical and elastic properties, Movement and multiplication of dislocations, Dislocation intersection and reactions. Partial dislocations and stacking faults. Application of dislocation theory to strengthening mechanism and yield point. Strain ageing and work hardening phenomena. Effect of strain rate and temperature on flow properties.

Creep: Generation and analysis of creep and rupture data. Dislocation and diffusion mechanisms of creep. Grain boundary sliding and migration. Deformation mechanism maps. Effect of metallurgical and test variation on creep and fracture. Superplasticity. Parametric methods for prediction of long time properties.
Fatique :Fatigue testing methods and machines. Stress controlled and strain controlled fatigue. Analysis of cyclic stress –strain data. Mechanism of fatigue crack, nucleation and propagation.
Fracture: Mode and mechanism of fracture, Griffith`s theory, Ductile to brittle transition. Transition temperature phenomena, Factors affecting transition temperature, Fracture mechanism, strain energy release rate, stress intensity factor, plane strain fracture, toughness, Design approach.
Fracture and fatigue of composites. Fractographic aspects of failure. Environment assisted fracture.

Reference Books:

1. Dieter G.E., Mechanical Metallurgy, McGraw Hill.
2. Hertzberg R.W., Deformation and Fracture Mechanics of Engineering Materials, John Wiley.

3. Hull D., Introduction to Dislocations, Pergamon.
4. Meyers M.A. and Chawla K.K., Mechanical Behavuior of Materials, PHI.

V SEMESTER

MT501 Steel Making: L-T-P-C (3-1-0-4)

Introduction: Principles of steel making reactions,viz decarburization, dephosphorization, desulphurization, silicon& manganese reaction.
Slag Theories: Molecular & ionic theories, Interpretation of the above reactions in terms of ionic theory of slag.
LD Process: Design of converter & lance, Quality of raw materials charged, Operation of the converter and control of bath and slag composition. Chemical reactions involved, Temperature and residual bath oxygen control. Use of oxygen sensor, some characteristics of L.D blow viz emulsion formation, slopping, maneuvering lance height for dephosphorisation and dacarburisation. Catch carbon technique, Recovery of waste heat, OBM/Q-BOP process, Concept and operation of the process. Mixed/ Combined blowing process. Oxygen top blowing with inert gas purging at bottom, Oxygen top blowing with inert and oxidizing gases at bottom, Oxygen top and bottom blowing, Steel making Scenario in India.
Open hearth Furnace: modification into twin hearth, operational principle, advantages.

Electric arc furnace: Advantages, charging, melting and refining practices for plain carbon and alloys steels. Use of DRI in arc furnaces and its effect on performance. UHP electric arc furnace with DC supply. Duplex processes of stainless steel making using VOD, AOD and CLU.
Induction Furnace: Advantages, Principles of induction heating, Use in steel industry.
Deoxidation of liquid steel: Requirement of deoxidizers, deoxidation practice, Stoke's law, use of complex deoxidizers, Inclusions and their influence on quality of steel. Killed, semi killed and rimming steels.
Secondary refining of steels: Objectives, principles of degassing, Different industrial processes such as DH, RH, VAD, SD, LF and ESR. Limitations and specific applications.
Continuous casting of steel: Advantages, Types of machines, Mould lubrication and reciprocation, Developments in Technology with respect to productivity, quality and energy conservation, Near Net shape casting, Strip casting.

Reference Books:

1. Tupkary R.H., An Introduction to Modern Steel Making, Khanna Publishers.
2. G.R. Bashforth, The Manufacture of Iron and Steel, Chapman & Hall.
3. Schrewe H.F. Continuous Casting of Steel, Stahl-eisen.
4. Edneral F.P., Electrometallurgy of Steel and Ferroalloys, Vol. 1&2, Mir.

MT502 Physical Metallurgy- II: L-T-P-C (3-1-0-4)

Theory of solidification: Nucleation and growth, mechanism of nucleation and driving force for growth. Morphology, Zone refining, crystal growth, crystallography, stabilization, Recovery, recrystallisation and grain growth. Annihilation of point imperfections, order disorder transformation, eutectoidal reaction, cellular reaction. Strengtheming mechanisms, massive and spinodal decomposition. Mechanism and kinetics of precipitation of age hardenable alloys.

Fe- C system: Effects of alloying elements, Formation of Austenite, Decomposition of Austenite, Pearlitic, Bainitic and Martensitic phase transformations, TTT and CCT diagrams, Hardenability, Critical diameter, Jominy end quench Test, Tempering of steel, Temper brittleness, Thermomechanical Treatment, , Ausforming, Maraging steels, Processing- structure property relationship in multiphase alloys, Rapid solidification processing, Metallic Glasses, Single crystal processing. Nano crystalline materials.

Reference Books:

1. Reedhill R.E., Physical Metallurgy Principles, Affiliated East West Press.
2. Avner S.H., Introduction to Physical Metallurgy, Tata McGraw Hill.
3. Porter D.A. & Easterling K.E., Phase Transformations in Metals and Alloys.
4. Clarke & Varney, Introduction to Physical Metallurgy.

MT503 Engineering Economics: L-T-P-C (3-1-0-4)

Definition, nature and scope of the subject, central problems of economic science, micro economics.

Theory of production: law of returns, marginal productivity theory, determination of optimum input levels under cost or output restriction, expansion path, long run and short run function, supply functions and elasticity of supply.

Theory of consumer behaviour: Determination of optimum levels of consumption. Income- consumption curve, derivation of demand function, elasticity of demand and slutsky's equation. Perfect competition and pricing of output. Market imperfections and the determination of equilibrium price and output. Classical and Keynesian theories of income employment and output. Multiplier and accelerator. Consumption function, capital budgeting. Theories of inflation, methods of credit control, fiscal policy and full employment. Cyclical fluctuations.

Reference Books:

1.Banga, T.R and Sharma, S.C, Industrial organization and Engineering Economics, Khanna Publishers.

2. Khanna, O.P, Industrial Engineering and Management, Dhanpat Rai and Sons

MT504 Foundry Technology: L-T-P-C (3-0-2-4)

Design and process selection in metal casting, Foundry processes

Patterns: materials and design, features of moulding processes, equipments, mechanizations, forces acting on moulds, mould factors in metal flow, molding factors in casting design.
Different types of binders and their uses in mould and core makings.

Melting of metals and alloys for castings: Brief mention of various melting units, melting & post melting treatments, melting practices as adopted for a few metals and alloys such as Cu, Al, Steel, Cast irons.

Solidification of metals and alloys: Nucleation, growth, role of alloy constitutions, thermal conditions and inherent nucleation and growth conditions in the liquid melt, significance & practical control of cast structure.

Principles of Gating and Risering: Feeding characteristics of alloys, types of gates and risers. Time of solidification and Chowrinov rule, wlodawer system for feeder head calculations, gating ratio, concept of directionality in solidification. Yield of casting and prescription for its augmentation.
Special casting methods: Investment casting, Die casting, centrifugal casting, Full mold casting, vacuum sealed casting. Thixo and Rheo casting, strip casting, near net shape casting. Development in modern casting processes.

Casting defects: A detailed analysis of casting defects, their causes and prescription of remedial measures.

Reference Books:

1. Heine R.W., Lopper C.R. & Rosenthal P.C., Principles of Metal Casting, McGraw Hill.
2. Davis, G.J., Solidification in Casting, Applied Sciences.
3. Beeley P.R., Foundry Technology, Butterworth.
4. Kondic V., Metallurgical Principles of Foundry, Edward Arnold.

MT505 Manufacturing Technology: L-T-P-C (3-0-2-4)

Introduction to different manufacturing processes, theory of joining processes, their importance and applications.

Powder Metallurgy: Introduction, Metal powder production methods.
Characterization of Powders: Composition & their structure, particle size & shape determination, treatment of metal powders. Powder flow, Compressibility and porosity measurements.

Behavior of powder during compaction, Die compaction, Types of presses, Tooling & Design. Modern methods of powder consolidation, Isostatic pressing, Roll compaction, powder extrusion & forging, slip casting.

Sintering of powders & evaluation of sintered products. Sintering theories, solid and liquid phase sintering, applications of sintered products.

Welding Metallurgy: Introduction to various welding processes (in brief)
Chemical reactions in welding: Gas- Metal reactions, Slag- Metal reactions, Effect of gaseous inclusions in weld metal.
Fusion Zone: Basic solidification concepts, Weld metal solidification, Post solidification phase transformations, Weld metal chemical inhomogenity.
Partially melted zone: Formation of partially melted zone, Difficulty associated with the partially melted zone.
Heat affected zone: Recrystallisation and grain growth in welding, Effect of welding parameters and process.
Weldability of common engineering materials like carbon and alloy steels, cast irons, stainless steels, Al- and Cu- based alloys, Welding defects and its remedies.

Reference Books:

1. Randal G., Powder Metallurgy, John Wiley.
2. Metal Powder Handbook, ASM.
3. Lancaster, J.F, Metallurgy of welding, Allen and Unwin.

MT506 Mechanical properties of materials & its evaluation: L-T-P-C (3-0-2-4)

Principles involved in:
Hardness Test: Types of Hardness Test, Brinell hardness, Analysis of indentation, Relationship between Hardness and the Flow Curve; Vicker's Hardness, Rockwell Hardness, Micro and Nano hardness tests, Hardness Conversion Relationship; Hardness at elevated Temperature.

Tensile Test: Specimen Geometry, Engineering and True Stress-Strain Curves, Evaluation of Tensile Properties, Strain Hardening and Plastic Instability. Testing Machines, Strain and Load Measuring Devices, Temperature and Strain Rate Effects.

Torsion Test: Mechanical Properties in Torsion, Torsional Stresses for Large Plastic Strains, Types of Torsion Failure, Tension Test Vs. Torsion Test, Hot Torsion Testing.

Impact Test: Notched Bar Impact Tests, Instrumented Charpy Test, Significance of Transition Temperature Curve, Metallurgical Factors affecting Transition Temperature

Fracture Toughness Test: Strain Energy Release Rate, Stress Intensity Factor, Fracture Toughness and Design, K_{IC} Plane Strain Toughness Testing, Plasticity Corrections.

Creep Test: Creep Curve, Stress Rupture Test, Structural Changes During Creep, Mechanism of Creep, Fracture at Elevated Temperatures, Prediction of Long Time Properties.

Fatigue Test: S-N Curve, Cyclic stress strain Curve, Low Cycle Fatigue, Effect of Stress concentration on Fatigue, Effect of Metallurgical Variables on Fatigue.

Unusual properties of ceramics, testing of ceramics. Non destructive testing of materials.

Reference Books:

1. Dieter G.E., Mechanical Metallurgy, Tata McGraw Hill.
2. Patratia Han (ed), Tensile Testing, ASM.
3. Boyer H.E. (ed), Hardness Testing, ASM.
4. Metals Handbook, 9th edition Vol. 8, Mechanical Testing, ASM.
5. Halmshaw R., Non Destructive Testing, Gordon & Breach.

VI SEMESTER

MT601 Metal Forming Technology: L-T-P-C (3-0-2-4)

Classification of metal forming processes, hot, cold and warm working. Flow curve for materials, effect of temperature, Strain rate and microstructural variables, residual stresses, experimental techniques, yielding theories, processing maps. Friction in metal working, Lubrication.

Rolling of Metals: Classification of rolled products, Types of rolling mills, Terminology used; Forces and Geometrical relationships in rolling, Rolling variables, Theories of design, Mill type, Lay out and rolling practice, adopted for some common products such as slabs, blooms, billets, plates, sheets etc., Rolling defects and their control.

Forging of Metals: Forging principles, Type of Forgings and equipment needed; Calculation of Forging load under sticking and slipping Plain strain forging analysis, friction conditions. Manufacture of rail wheels and tyres. Forging defects and their control.

Extrusion: Types, Principles and equipments, Variables in extrusion, deformation in extrusion, Calculation of extrusion pressure under plain strain conditions, extrusion defects, production of tubes and seamless pipes.

Wire drawing: Drawing of rods, wire and tubes, Calculation of drawing loads, drawing defects.

Sheet metal forming: Forming methods such as bending, stretch forming, shearing, blanking, deep drawing and redrawing. Formability diagrams, Defects in formed products.

Special forming methods such as high energy forming: explosive forming, electrohydraulic and magnetic forming processes.

Reference Books:

1. Dieter G.E., Mechanical Metallurgy, McGraw Hill.
2. Harris J.N., Mechanical Working of Metals- Theory and Practice, Pergamon.

3. Kalpakjian S. and Schmid S.R., Manufacturing Processes for Engineering Materials, Pearson.

MT602 Corrosion Science and Engineering: L-T-P-C (3-0-2-4)

Introduction, Importance of Corrosion, Economics of corrosion.
Electrochemical and thermodynamic principles, Nernst equation and electrode potentials of metals. EMF and Galvanic series, Merits and demerits; Origin of Pourbaix diagram and its importance.
Exchange current density, Polarisation, Concentration, Activation and Resistance, Tafel equation; Passivity, Electrochemical behaviour of active/ passive metals, Flade potential, Theories of passivity.
Atmospheric, Pitting, Dealloying, Stress corrosion cracking, intergranular corrosion, Corrosion fatigue, Fretting corrosion and high temperature oxidation, Causes and remedial measures.
Purpose of testing, laboratory, semi plant and field tests, susceptibility tests for IGC, strees corrosion cracking and pitting, sequential procedure for laboratory and onsite corrosion investigations, corrosion auditing and corrosion map of India.
Corrosion prevention by design improvements, anodic and cathodic protection, metallic, non metallic and inorganic coatings, Mechanical and chemical methods, Various corrosion inhibitors.

Reference Books:

1. Fontana M.C., Corrosion Engineering, McGraw Hill.
2. Glasstone S., An Introduction to Electrochemistry, Van Nostrand.
3. Narain S. and Saran R., An Introduction to Electrometallurgy, Standard Publishers.
4. Scully J.C., The Fundamentals of Corrosion, Pergamon.

MT603 Extraction of Non Ferrous Metals: L-T-P-C (3-1-0-4)

General principles of extraction of metals from oxides and sulphides; Mineral resources of Non ferrous metals in India; Their production, consumption and demand. Future of Non ferrous metal industries in India.
Aluminum: Bayer's process and factors affecting its operation, Hall- Heroult process: Principle and practices, anode effect, refining of aluminum. Alternate methods of production of alumina and aluminum.
Copper: Roasting of sulphides, Matte smelting, Converting; Refining, Byproducts recovery; Recent developments, Continuous copper production processes, Hydrometallurgy of Copper.
Zinc: Pyrometallurgy of Zinc; Principle and practices of roasting; sintering and smelting; Hydrometallurgy of Zinc.
Lead: Agglomeration of galena concentrates and roasting, blast furnace smelting, refining of lead bullion.

Uranium: Process for the digestion of uranium ores; Purification of crude salts; Production of reactor grade UO_2.
Titanium: Methods of upgrading Ilmenite; Chlorination of Titania, Kroll and Hunter processes; Consolidation and refining.
Other Metals: Simplified flow sheets and relevant chemical principles of extraction of Ni, Mg, Au, Ag, Sn, Zr.

Reference Books:

1. Ray H.S., Sridhar R. & Abraham K.P., Extraction of Non Ferrous Metals, Affiliated East West.
2. Biswas A.K. & Davenport W.G., Extractive Metallurgy of Copper, Pergamon.
3. Zelikman A.N., Krein O.E. & Samsonov G.V., Metallurgy of Rare Metals, Israel Program for Scientific Translation.
4. Burkhin A.R. (ed), Production of Al & Al_2O_3, Wiley.

MT604 Heat treatment Technology: L-T-P-C (3-0-2-4)

Objectives and variables involved in heat treatment. Role of alloying elements including microalloying. Decomposition of Austenite, Pearlitic, Bainitic and Martensitic transformations. Limitations of Fe- C diagram. TTT and CCT diagrams.
Annealing: (Full, Homogenising, spheroidisation and stress relieving), Normalising, Comparison of annealing and normalizing.
Hardening: Objectives, Volume and surface hardening, Austenitising temperature and internal stresses, Quenching medium and methods, Retained austenite and defects in hardening. Tempering of steels, Aims and stages of tempering, Tempering of alloy steels and multiple tempering.
Thermomechanical treatment of steels, Principles and practices. Ausforming and isoforming; Heat treatment of alloy steel castings and forgings. Heat treatment of cast iron, malleable cast iron and S.G iron.
Heat treatment of general engineering steels: Stainless steel, Hadfield steel, Spring steels, Bearing steels, Tool steels, HSLA steels, Maraging steels and dual phase steels.
Heat treatment of Non ferrous metals and alloys, Brasses, Bronzes, Al and Mg - alloys.
Heat treatment defects and their rectification. Advances in heat treatment technology.

Reference Books:

1. Reed Hill R.E., Physical Metallurgy Principles, Affiliated East West.
2. Sharma R.C., Principles of Heat Treatment of Steels, New Age International.
3. Sinha A.K., Physical Metallurgy Handbook, McGraw Hill.
4. Singh V., Heat Treatment of Metals, Standard Publishers.
5. Brooks C.R., Heat Treatment, Structure and Properties of Non Ferrous Alloys, ASM.

MT606 Characterization of Materials: L-T-P-C (3-0-2-4)

Scanning electron microscope, Modes of operation, Study of surface topography and elemental composition analysis, Electron probe analysis (EPMA/ EDX) and Auger spectroscopy.

Transmission electron microscopy, Imaging and different modes, bright and dark field imaging, selected area diffraction, specimen preparation techniques.

Advanced microscopic techniques: AFM

Thermal characterization techniques: Theory, TGA, Instrumentation, applications. DTA, Apparatus, methodology, applications; DSC, applications, Dilatometer.

Chemical characterization techniques: Principle underlying techniques, Infrared spectroscopy, Emission spectroscopy, Chromatography techniques. Resistivity and Magnetic measurements. Structure- Property co-relationship.

Reference Books:

1. Cullity B.D., Elements of X-Ray Diffraction, Addition Wesley.
2. Shridhar G., Ghosh C.S. and Goswami N.G., Materials Characterization Techniques. (ed), NML Jamshedpur.
3. Williams, D.B. & Carter C.B. , Transmission Electron Microscopy: A Text Book of Materials science.
4. Krishna, R., Ananthraman T.R., Pande C.S., Arora, O.P., Advanced Techniques for Microstructural Characterization (ed), Trans Tech Publication.

VII SEMESTER

MT701 Composite Materials: **L-T-P-C (3-1-0-4)**

Introduction to composites, Matrices, Reinforcements, Classifications, applications, advantages, Fundamental concept of reinforcement, Review of current developments.

Design, fabrication and economic considerations; Basic mechanics of reinforcement, Stiffness of parallel arrays of fibers in a matrix. Discontinuous and particulate reinforcement. Fibers and Resin materials.

Rule of mixtures, critical fiber length, Short and continuous fibers, Fiber orientations; Matrix and reinforcement materials, Polymeric matrices, Metallic matrices, Ceramic matrices, Particulates, flakes, whiskers, Fibers: Glass, aramid, alumina, silicon carbide.

Nature and Manufacture of Glass, Carbon and aramid fibers. Review of the principal thermosetting and thermoplastic polymer matrix systems for composites.

Polymer matrix composites, CFRP and carbon- carbon composites; Types, Manufacturing, processing methods, Interfaces, Properties, Applications. Toughening mechanisms, Fiber forms, Prepregs, The role of interface. The nature of fiber surfaces, Wetting and adhesion, Strength, stiffness, fracture toughness and toughening mechanism of composites, strength of unidirectional composites. Application of fracture mechanics to composite materials.

Synthesis and properties of nano composites.

Reference Books:

1. Chawla, Composite Materials Science and Engineering, Springer.
2. Hull, An Introduction to Composite Materials, Cambridge.
3. Mathews and Rawlings, Composite Materials: Engineering and Science, Chapman and Hall.

MT702 Computer applications in Metallurgy: L-T-P-C (3-1-0-4)

Numerical methods for solution of ordinary differential equations. Application of regression analysis and curve fitting techniques.
Calculation of phase diagrams, stereographic projections. Computer applications for energy & material balance in B.F. and BOF Steel making processes.
Numerical solution of partial differential equations pertinent to heat, mass & momentum transfer. Computer applications in solidification, potential energy diagrams and experiments in metallurgy. Analysis of test data using softwares.

Reference Books:

1. Chapra S.C. and Canale S.C., Numerical Methods for Engineers, Tata McGraw Hill.
2. Szekley J.S., Evans J.W. and Brimakombe J.K., The Mathematical and Physical Modeling of Primary Metals Processing Operations, Wiley.

MT703 Environment & Pollution Control in Iron& Steel Industry:L-T-P-C(3-0-2-4)
Various types of solid, liquid and gaseous pollutants and their harmful effects; Environmental impact assessment in metallurgical Industries; Pollutant emissions from integrated iron and steel plants, Sponge iron plants, coal washeries. Environmental aspects of coal and metal mines; Management of solid, liquid and gas wastes generated during iron and steel making operations; Environmental audit; Preventive measures to reduce atmospheric pollution from these industries; scope of alternative energy sources to combat pollution from metallurgical industries. Environmental legislation related to metallurgical industries.

Reference Books:

1. Pandey, G.N, A Text book for energy system engineering, Vikas publishing
2. Rao, C.S, Environmental pollution control Engineering, Wiley Eastern Limited
3. Ray, H.S et al (ed), Energy and the mineral and metallurgical industries, Allied publishers
4. Nathanson, J.A, Basic environmental Technology, Prentice Hall

MT704 Industrial Engineering and Management: L-T-P-C (3-1-0-4)

Factory Planning**:** Types of industrial organizations, organizational structures. Management functions and concepts. Plant location and layout.

Financial Management: Functions, Relevance of fixed and working capital, Elements of cost, Depreciation, Break even analysis, Budget and budgetary control.

Production Management: Production and productivity, productions, planning & control, sales fare casting, Inventory control.

Project Management: Elementary concepts of operation research, networking, CPM & PERT. Concepts of quality control, statistical quality control, quality circles and total quality management, ISO standards.

Personnel Management: Leadership & motivation work study, time and motion, wages and incentives.

Management information system: Aims, Characteristics, Designs and implementation.

Entrepreneurship: Relevance and benefit, Essential qualities of Entrepreneur, preparation of prefect report, feasibility study, Market survey, Agencies available for financial and technical assistance.

Reference Books:

1. Bangra T.R. & Sharma S.C., Industrial Organization and Engineering Economics, Khanna Publishers.
2. Khanna O.P. Industrial engineering and Management, Dhanpat Rai & Sons.
3. Gupta C.B. & Shrinivasan N.P., Entrepreneural Development, S.Chand & Sons.
4. Shrinath L.S. PERT and CPM- Principles and Application, Affiliated East West.

VIII- SEMESTER

MT801 Organisational behavior and Industrial Psychology: L-T-P-C (3-1-0-4)

Scope of scientific psychology & industrial psychology, Basis process, perception.

Training & Learning: Human variables, selection and placement: Intelligence, MA & IQ measurement.

Personality: Development, Approaches, Assessment, tests, selection and placement, job analysis, interviewing, psychological test, decision making process, motivation and work;

Needs: Hierarchy of needs, leadership, supervision.

Ergonomics: Three process, work space & human factors in job design. Working environment, noise, atmospheric conditions and illumination.

Reference Books:

1. Parrek U., Understanding Organizational Behavior.
2. Robbins S., Organizational Behavior.
3. Luthans F., Organizational Behavior.
4. Prasad L.M., Organizational Behavior, S. Chand.

MT802 Total Quality Management: L-T-P-C (3-0-0-3)

Probability statistics: Statistical parameters for quality assurance; Prediction of process or product quality using normal distribution.

Sampling inspection: Plastic selection of sampling schemes for attributes and variables; Use of control charts for attributes and variables.
Destructive tests including fracture toughness testing.
Non destructive methods of inspection for castings, forgings and weldments;
Radiography, ultrasonic, magnetic particle, eddy current, die penetrant, holography, optical microscopy, photo micrography; Fracture tests; Principles of automatic inspection, test and assembly vision systems. Monitoring of production equipments, elements of fault diagnostics. Failure analysis, Analysis of castings, forgings & welding defects.

Reference Books:

1. Banga, T.R and Sharma, S.C, Industrial organization and Engineering economics, Khanna publishers
2. Khanna, O.P, Industrial Engineering and Management, Dhanpat Rai and Sons.
3. Halmshaw, R, Non destructive Testing, Gordon and Breach
4. Baldevraj, Jay Kumar and T, Thavasimuthu, M, Practical Non destructive Testing, Narosa Publishers.

MT803 Advanced Materials: L-T-P-C (3-0-0-3)

Processing of Advanced materials: Super plastic, spray forming, rapid solidification. Materials selection and design
Nanostructures, Nano materials, Nano composites.
Bio materials: Metallic bio materials like 316L stainless steel, Co-Cr alloys, Ti6 Al4V, ceramic bio materials like Alumina, Zirconia, carbon hydroxyapatite, polymeric bio materials like ultra high molecular weight polyethylene, polyurethane.

Smart Materials: Piezo electric materials, shape memory alloys and shape memory polymers.

High performance alloys: Nickel super alloys, Ti-alloys, Al-Li alloys, Haste alloy, Inconel, Monel, Nitronic, Co-based alloys and commercially available pure Ni-alloys.

Nuclear Materials: Materials for nuclear reactors such as fuels, moderators, control rods, coolants, reflectors and structural materials. Fabrication of fuel and cladding materials.

Reference Books:

1. Gandhi M.V., Thompson B.S., Smart Materials and Structures, Chapman and Hall.
2. Ray A.K. (ed), Advanced Materials, Allied Publishers.
3. Rama Rao P. (ed), Advances in Materials and Their Applications, Wiley Eastern Ltd.
4. Bhushan B., Nano Technology (ed), Springer.

MT605 ELECTIVE-I

Physics of Metals: **L-T-P-C (3-1-0-4)**

Crystallography: Crystalline and amorphous structures, Elements of crystal symmetry, symmetry elements and axes, two, three, four and six fold symmetry, review of atomic bonding.

Order-disorder transformations: Ordering, Degrees of long range and short range ordering, Anti phase domain, super lattice, Elements of super lattice theories, properties and applications.

Electron theory of Metals: Heisenberg's uncertainty principle, Schrodinger's equation, free electron theory, Zone theory, Density of states, Fermi energy level, Application of zone theory to alloy phases; Conductors and insulators, semi conductors, P- and N- type semi conductors.

Magnetic Properties: Dia, Para and Ferro- magnetism, Domain theory of Ferro magnetism, Anti ferromagnetism and Ferrites, Hysteresis loop, soft magnetic materials, Hard magnetic Materials, Super conductivity, BCS theory, Type- I and Type- II super conductors.

Elements of X-ray diffraction: X- Ray, Bragg's Law, Lau, Rotating crystal and powder methods, structure determinations with the help of X-Ray. Stereographic Projections.

Reference Books:

1. Reed Hill R.E., Physical Metallurgy Principles, Affiliated East West.
2. Kakani S.L. and Kakani A., Materials Science, New Age International.
3. Higgins R.A., Engineering Metallurgy, Standard Publishers.
4. Raghavan V., Materials Science and Engineering, PHI.

Methoding of casting: **L-T-P-C (3-1-0-4)**

Principles of casting design, pattern design considerations, pattern allowances, pattern design and construction.

Design of different types of cores and core prints Fundamentals of fluid flow, design of gating system, slag traps and filters etc.

Directional and progressive solidification, differential methods of feeder design, feeding distance, feeding efficiency, feeder aids.

Reference Books:

1. Heine R.W., Lopper C.R. & Rosenthal P.C., Principles of Metal Casting, McGraw Hill.
2. Davis, G.J., Solidification in Casting, Applied Sciences.
3. Beeley P.R., Foundry Technology, Butterworth.
4. Kondic V., Metallurgical Principles of Foundry, Edward Arnold.

Materials Handling: **L-T-P-C (3-1-0-4)**

Objectives of material handling systems, material handling engineering survey, basic features of handling, types of material handling systems, various material handling considerations including combined handling, space for movements, analysis of handling methods, economical and technical considerations of handling equipments, cost analysis of material handling systems.
Material handling equipments, types of material handling equipment; selection and maintenance of material handling equipments used in foundries, forging machinery and assembly shops. Lifting and lowering devices, Conveying devices; Design of belt conveyers, Use of limit switches and Micro processors, Programmable logic controllers; Automation in Foundries; Use of robots; Kinematics of industrial robots. Amount of equipments required and predicting in process inventory by graphical technique.
Procedures for travel charting, numerical problems in optimum arrangement of various departments and shops under given constraints and to check their effectiveness.

Reference Books:

1. Plant Layout and design, Moore
2. Plant Layout and Material handling, Apple
3. Plant Layout, Shubhin
4. Construction management, Verma, M.

Failure Analysis: **L-T-P-C (3-1-0-4)**

Types of failure and techniques for failure analysis
Failure data retrieval, Procedure steps for investigation of a failure for failure analysis.
Failure analysis methodology, Tools and Techniques of Failure analysis.
.
Reliability concept and hazard function, life prediction, condition monitoring, application of Poisson, Exponential and Weibull distributions for reliability, bath tub curve, parallel and series system, mean time between failures & life testing.

Some case studies of failure analysis.
Introduction to quality management, concept of ISO 9000, ISO 14000, QS 9000;
Inspection; Inspection by sampling.
Reference Books:

1. Metals Handbook, Failure Analysis and Prevention, Vol.10 ASM.
2. Colangelo V.J. & Heiser F.A., Analysis of Metallurgical Failures, John Wiley.

Alternative routes of Iron and Steel making: **L-T-P-C (3-1-0-4)**

Need for the development of alternatives, classification of processes.
Thermodynamic and kinetic concepts of iron ore reduction in solid and liquid state using solid/gaseous reductants.

Selection of reductants, heat and mass transfer, energy consumption and operating problems; storage, transportation and utilization of sponge iron in India.

Sponge iron production using shaft, kiln, retort and rotary hearth reactors. Raw materials preparation; Midrex, Hyl, Circored , FIOR processes; SL/RN, CODIR, ACCAR, TDR processes; Fastmet process.
Pre reduced iron ore pellets for B.F applications, concept of composite pellets and its feasibility. Iron powder and Iron carbide preparation from fluidized bed reactors and other processes; operating problems.
Smelting reduction processes; Principles, Classifications, merits and limitations. COREX, FINEX, Hismelt, DIOS and Electric Smelting processes.

Direct steel making; Continuous steel making processes such as IRSID Process, IFCON process.

Continuous casting, Developments such as flow control devices in tundish, sequence casting, high speed casting, detection/prevention of caster breakouts, electro magnetic stirring, thin slab casting, strip casting.
Slag: Measurement of critical properties, use of process modeling; design and selection of slag and refractories.

Reference Books:

1. Von Bogdandy and L. Engell, H.J, Reduction of iron ores, Springer

2. Catterjee, A., Singh, R and Pandey, B, Metallics for steel making, Allied publishers
3. Proceedings of International conference on Alternative routes to Iron and Steel under Indian conditions, IIM, Jamshedpur, 1988
4. Rogers, R.R, Proceedings of symposium on Iron ore reduction, Pergamon

Ceramic processing and structural ceramics: **L-T-P-C (3-0-2-4)**

Powder processing, preparation and consolidation of powders, sintering, spark plasma and micro wave sintering, shock compaction, severe plastic deformation, near net shape forming, self sustaining high temperature synthesis, sol-gel processing, laser processing.

Structural ceramics: Properties and applications, mechanical behavior of different structural ceramics, brittleness of ceramics, concept of fracture toughness and different toughness measurement techniques, Elastic modulus, strength measurement, weibull theory. Processing and manufacturing technologies for non-oxide and oxide based structural ceramics.

Spray formed tooling for rapid manufacture, plasma spray coating.

Reference Books:

1. Kingery W.D. Bowen, H.K. Uhlhmen D.R., Introduction to Ceramics, John Wiley.
2. Richerson D.W., Modern Ceramic Engineering- Properties Processing and Use in Design, CRC Press.
3. Chiang Y.M., Birnie D.P., Kingery W.D., Physical Ceramics: Principle of Ceramic Science and Engineering, John Wiley.
4. Norton F.H., Elements of Ceramics, Addison Wesley.

MT705 ELECTIVE-II

Electronic, optical and magnetic properties of Materials: **L-T-P-C (3-1-0-4)**

Review of free electron and band theories of solids, electrical conduction in metals and semiconductors, Hall effect, Temperature dependence of electrical conductivity, Thermal conductivity. Thermoelectric properties of metals and semiconductors.
Ionic conductivity, Super conductivity, Piezoelectric and ferroelectric properties of dielectric materials.
Introduction to magnetism; Diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism and ferrimagnetism. Calculation of magnetic moment, Soft and hard magnetic materials.
Optical properties, Refraction, Absorption, Absorption in dielectrics, photographic images, Luminescence, Lasers.

Classification, methods of manufacture and fabrication techniques. Applications of these properties in optical fibers, magnetic data storage, solar cells, transistors and other devices.

Experimental determination of the electronic, optical and magnetic properties of materials.

Reference Books:

1. Hummel, R.E, Electronic properties of Materials, Springer
2. Raghavan, V, Materiasls Science and Engineering, Prentice Hall
3. Azaroff, L.I, Magnetic Materials
4. Kasap, S.O, Principles of electronic materials and devices, Tata McGraw Hill

Modern NDT: **L-T-P-C (3-0-2-4)**

Review of conventional methods of non destructive testing.

Acoustic emission inspection: Types, basic concepts, instrumentation and read out, signal description, background noise, inspection of pressure vessels, flaw location, inspection of wire ropes, welds, ceramic materials, composite materials.

Leak Testing: Visible indications, electronic indications, basic methods of leakage measurements, characteristics of gaseous tracers in leak testing, reference standards. Calibration of standard reference leaks, safety aspects of leak testing.

Thermography: Contact and non contact inspection methods, heat sensitive paints and papers; thermally quenched phosphors liquid crystals, techniques for applying liquid crystals, calibration and sensitivity; other temperature sensitive coatings; non- contact thermographic inspection- advantages and limitations, infrared radiation and infrared detectors. Instrumentation and methods, applications.

Optical holography: Laser fundamentals, holography, recording and reconstruction, holographic interferometry, real time, double exposure and time averaged techniques, holographic NDT, methods of stressing and fringe analysis, typical applications, advantages and limitations.

Acoustical holography: Liquid surface acoustical holography, optical system, object size and shape, sensitivity and resolution, commercial liquid surface equipment; scanning acoustical holography, reconstruction, object size, sensitivity and resolution, commercial scanning equipment, read out methods, calibration, interpretation of results, applications, inspection of welds in thick materials.

Stress analysis: Polariscope, calibration of photoelastic materials, isochromatic and isoclinical fringes, stress determination, time edge effects, Moire fringes techniques, photo elasticity, strain gauges, X- ray residual stress analysis.

Magnetic resonance imaging: Magnetic resonance phenomena, chemical shift, relaxation phenomena, back projection imaging, practical consideration of experimental set up, magnetic resonance imaging systems, applications.

Acceptance standards.

Reference Books:

1. Miller, R and Paul, M; Non destructive testing handbook; Acoustic emission testing, Vol 5, American society for non destructive testing, 1987.
2. Spanner, J.C; Acoustic emission techniques and applications., Latex publishing, 1974
3. American Society for Metals, Non destructive inspection and quality control; Metals handbook, Vol 11, 8th edition.
4. ASM handbook, Non destructive testing and quality control, Vol. 17.

Metal Joining: **L-T-P-C (3-0-2-4)**

Introduction: Theory and classification of welding and other joining processes. Manual metal arc (MMA): Equipment requirement, electrodes for welding of structural steels, coating, constituents and their functions, types of coatings, current and voltage selection for electrodes for welding, power sources; conventional welding transformers, rectifiers, current and voltage. The influence of power sources on welding, Metal transfer.

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

Gas metal arc welding or MIG/MAG welding: Process details, shielding gases, electrode wires, their sizes and welding current ranges.
TIG Welding: Process details, power source requirements, electrode sizes & materials, current carrying capacities of different electrodes, shielding gases, applications..

Resistance welding: General principle of heat generation in resistance welding, application. Process details & working principles of spot, seam and projection welding. Electrode materials, shapes of electrodes, electrode cooling, selection of welding currents, voltages. Welding metallurgy of carbon and alloy steels, cast irons, stainless steels, Al-and Cu- based alloys.

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

Reference Books:

1. Lancaster J.F., Metallurgy of Welding, Allen and Unwin.
2. Little R.L., Welding and Welding Technology, TMH.
3. Norrish J., Advanced Welding Processes, Woodhead.
4. Wenman K., Welding Processes Handbook, Woodhead.

Polymer Technology: **L-T-P-C (3-1-0-4)**

Introduction: Polymer materials, Classification, Types of polymerization, mechanisms, statistical approach, catalysts in polymerization, Molecular weight determination. Methods of molecular weight characterization.
Semi crystalline and amorphous polymers, Elastomers, Additives, Fillers, Viscoelasticity, Molecular theory of viscoelasticity. Mechanical, thermal, optical and electrical properties of plastics with reference to important engineering plastics like LDPE, HDPE, PVC, Polyester, Phenol formaldehyde, alkyds, cellulose etc.
Fabrication technology and polymer processing, moulding practices, extrusion, application of polymers and plastic fibers, elastomers, adhesives, bio medical applications, fiber reinforced plastics, conducting polymers.

Reference Books:

1. Thomes N., Young and Lovell, Introduction to Polymers.
2. Billmeyer F., A Textbook of Polymer Science.

Instrumentation and Control: **L-T-P-C (3-0-2-4)**

Generalized measurement systems. Basic standards; static and dynamic measurements; measurement of temperature, pressure, velocity, force strain, vibration and acceleration by transducers. Role of transducers in automatic control systems, Feed back systems and their characteristics. P.I.D. controllers; Response characteristics and compensation of electrical, hydraulic and pneumatic systems.

Energy conservation and management in Iron & Steel Industry: **L-T-P-C (3-1-0-4)**

World energy resources: Fossil fuels, Nuclear energy, Biomass energy, solar energy, wind energy, Geothermal energy etc.
Present day energy scenario in the world and India in particular; Consumption of fossil fuels in chemical, metallurgical and power industries and automobiles.
Pollutant emissions from major fossil fuel consuming industries/sectors and their local and global effects.

Renewable energy sources: Potentials, possible applications and impact on environmental pollution; world wide approach in abatement of pollution emissions and conservation of fossil fuels.
Solid, liquid and gaseous wastes generated from metallurgical industries: their recycling, reuse and management; municipal wastes and their energy potentials; waste heat recovery; Environmental legislations.

Reference Books:

1. Ray H.S. et al (ed), Energy and the Mineral and Metallurgical Industries, Allied Publishers.
2. Pandey G.N., A Textbook on Energy System Engineering, Vikas Publishing.
3. Rao C.S., Environmental Pollution Control Engineering, Wiley Eastern Ltd.
4. Nathanson J.A., Basic Environmental Technology, PHI.
5. Gupta R.C. (ed), Proc. Environmental Management in Metallurgical Industries, Allied Publishers.

MT804 ELECTIVE-III

Secondary steel making: **L-T-P-C (3-1-0-4)**

Objectives and techniques adopted in secondary steel making.
Vacuum degassing processes: ladle degassing processes (VOD, VAD), Steam degassing processes, circulation degassing processes (RH,DH), Inert gas purging, ladle furnace etc.
Role of slag and powders in inclusion control: Desulphurization, Dephosphorisations. Modification of inclusion morphologies, production of ultra low carbon, ultra low sulphur, ultra low phosphorus and inclusion free steels. Powder injection systems. Production of alloy steel through post solidification treatments (VAR, ESR); Refractories used in secondary steel making furnaces, their properties and selection criteria. Process selection in secondary steel making.

Reference Books:

1. Ghosh A., Secondary Steelmaking- principle & Applications, CRC Press.
2. Ghosh A., Principles of Secondary Steelmaking Processing and Casting of Liquid Steel, Oxford & IBH Publication.
3. Ghosh Ahindra, Chatterjee A., Ironmaking and Steelmaking Theory and Practices, PHI Pvt. Ltd.

X-Ray crystallography: **L-T-P-C (3-1-0-4)**

Use of X-Rays, electrons and neutrons for diffraction studies Fundamentals of crystallography, Reciprocal lattice. X-ray diffraction, Bragg's law, Factors affecting intensities of diffracted beams.
Atomic scattering factor, structure factor, integrated intensity of diffracted beam, temperature factor, line broadening, Lorentz polarization factor.
Powder diffraction methods: Lau patterns and orientation of single crystals. Lau, powder & rotating crystal method.
Electron diffraction: selected area diffractions, convergent beams, electron diffraction and micro diffraction, Analysis of diffraction patterns.
Stereographic projections.
Techniques for studying bent crystals, textures, order-disorder transformations.
Reference Books:

1. Cullity B.D., Element of X-Ray Diffraction, Addition Wesley.
2. Barret C.S. and Massalki T.B., Structure of Metals, McGraw Hill.
3. Chaterjee S.K., X-Ray Diffraction, its theory and applications.
4. Goodhow P.J., J. Humhreys, R. Beanland, Electron Microscopy & Analysis Taylor and Fransis publication.

Forging Die Design: **L-T-P-C (3-1-0-4)**

Job analysis, designer's drawing, standards for forging tolerances and allowances, forging drawing, preliminary die design considerations like parting line position, rib and web dimensions, draft angle, filler and corner radii etc.
Design of flash and gutter, preform design, insert design, finishers, blockers, design consideration.
Design of upseter and piercing tools, Design of trimming and punching die and tools. Estimation of forging load and energy. Computer aided design of forging dies. Automation in forge shops. Materials and properties of forging dies. Heat treatment of dies and tools. Problems of die wear estimation and remedial measures. Role of lubricants in hot and cold forgings of ferrous, non ferrous metal and alloys.
Noise and vibration control in forge shops. Recent developments in technology of die forging. Economics of die design.

Reference Books:

1. Thomas, A. Forging Die design
2. Thomas, A. Forging Methods
3. Alton, Forging Die design and Practice
4. Cold and Hot Forging, Fundamentals and applications, ASM

Selection of Engineering Materials: **L-T-P-C (3-1-0-4)**

Technologically important properties of materials, Physical, chemical, mechanical and electrical properties of metals.
Materials selections: Methodology of materials selection, Identification of required properties and materials index parameters based elastic, yield, fracture, fatigue and creep limited design. Selection of materials based on available property data and optimization to select the best materials.
Case studies: Pressure vessels, turbine blades, boiler tubes, oil/gas pipe lines, bearings, gears, springs, engine components, aero structures etc.

Reference Books:

1. Ashby, M.F and Jones, R.H, Engineering Materials, Vol.1 &2, Pergamon.
2. Tein J.K. and Ansell (eds.): Alloy and Microstructural Design, Academic.
3. Pickering F.B, Physical Metallurgy and Design of Steels, Applied Sciences.
4. Material Selection and Design, ASM Handbook, Vol.2

Nano Materials and its applications: **L-T-P-C (3-1-0-4)**

Introduction: Types of nano materials, emergence and challenges in Nano Technology.
Synthesis routes for nano materials.
Bottom up and top down approaches; solid, liquid and gas phase synthesis, hybrid phase synthesis.
Synthesis of bulk nano structured materials: Approaches & challenges.

Properties of nano materials: Stability of nano materials, mechanical properties, optical, electrical and magnetic properties, Nano-diffusion.

Characterization of nano materials: Structural characterization by XRD, SEM, TEM, SPM.
Chemical characterization by spectroscopy techniques, characterization of mechanical properties by nano indentation, hot compression testing, Fracture analysis.

Application of nano materials: Electronics and optoelectronic applications, nano dots, biological applications, catalytic applications, quantum devices, application of carbon nano tubes, nano fluids, Future of Nano Technology.

Reference Books:

1. Pradeep T. Nano: The Essentials, McGraw Hill Publishing Co Ltd.
2. Mick Wilson et al, Nanotechnology, Overseas Press India Pvt. Ltd.
3. Charles P. Poole, Jr. Frank J. Owens, Introduction to Nano Technology, Wiley.
4. Gunter Schmid, Nanioparticles: From Theory to applications, Wiley-VCH Verlag Gmbh & Co.