Proposal

B.TECH.

(Met.Engg.)

FOUR YEARS

DEGREE

COURSE

December 5, 2006 **Faculty Meeting**

PART II, SEMESTER III

Subjects	Credits	Contacts hrs/week	Minimum contact hrs/Sem.
Theory:			
AM-2107A Computational Methods	3	3	30
MN-2107B Mineral Benefication	3	3	30
MT-2101 Principles of Extractive Metallurgy	3	3	30
MT-2102 Metallurgical Thermodynamics	4	4	40
MT-2103 Structure of Materials	4	4	40
MT-2104 Materials Testing	3	3	30
Total for Theory	**20**	**20**	**200**
Practicals:			
MN-2307C Mineral Benefication	2	3	30
MT-2305 Physical Metallurgy	2	3	30
MT-2306 Extractive Metallurgy	2	3	30
Total for Practicals	6	9	90
Total for Semester III	**26**	**29**	**290**

PART II, SEMESTER IV

Subjects	Credits	Contacts hrs/week	Minimum contact hrs/Sem.
Theory:			
EE-2207D Electrical Engineering	3	3	30
MT-2207 Fuels and Refractories	3	3	30
MT-2208 Electrometallurgy & Corrosion	3	3	30
MT-2209 Phase Diagrams	3	3	30
MT-2210 Metallography Techniques	4	4	40
MT-2211 Mechanics of Deformation and Fracture	3	3	30
Total for Theory	**19**	**19**	**190**
Practicals:			
MT-2412 Metallography	2	3	30
MT-2413 Mechanical Testing	2	3	30
MT-2414 Electrometallurgy & Corrosion	2	3	30
Total for Practicals	6	9	90
Total for Semester IV	**25**	**28**	**280**
Total for Part II	**51**	**57**	**570**

PART III, SEMESTER V

Subjects	Credits	Contacts hrs/week	Minimum contact hrs/Sem.
Theory:			
MT-3115 Phase Transformations	3	3	30
MT-3116 Mechanical Behaviour of Materials	3	3	30
MT-3117 Non-ferrous Extractive Metallurgy	4	4	40
MT-3118 Iron Making	4	4	40
MT-3119 Foundry Metallurgy	3	3	30
MT-3120 Instrumental Analysis	4	4	40
Total for Theory	**21**	**21**	**210**
Practicals:			
MT-3321 Computer Applications	2	3	30
MT-3322 Ferrous Metallurgy	2	3	30
MT-3323 Foundry Metallurgy	2	3	30
Total for Practicals	6	9	90
Total for Semester V	**27**	**30**	**300**

PART III, SEMESTER VI

Subjects	Credits	Contacts hrs/week	Minimum contact hrs/Sem.
Theory:			
HU-3207E Open Elective (Humanities)*	3	3	30
MT-3224 Heat Treatment	4	4	40
MT-3225 Mechanical Working	3	3	30
MT-3226 Steel Making	4	4	40
MT-3227 Transport Phenomena	3	3	30
MT-3228 Fundamentals of Metallurgical Processes	3	3	30
Total for Theory	**20**	**20**	**200**
Practicals:			
MT-3429 Heat Treatment	2	3	30
MT-3430 Transport Phenomena	2	3	30
MT-3431 Group Discussion	1	2	20
Total for Practicals	5	8	80
Total for Semester VI	**25**	**28**	**280**
Total for Part III	**52**	**58**	**580**

- **Open Elective (HU-3207E) common to the entire Faculty, any one of the following:-**
  History of Science and Technology
  Industrial Psychology
  Environment and Ecology
  Energy Management
  Industrial Sociology
  Human Values

PART IV, SEMESTER VII

Subjects	Credits	Contacts hrs/week	Minimum contact hrs/Sem.
Theory:			
MT-4132 Modelling and Simulation	3	3	30
MT-4133 Materials Fabrication Technology	3	3	30
MT-4134 Materials Selection and Design	3	3	30
MT-4135 Non-metallic Materials	3	3	30
MT-4136 to MT-4139 Elective I	3	3	30
Total for Theory	**15**	**15**	**150**
Practicals/Project:			
MT-4340 Metal Fabrication and Non-destructive Testing	2	3	30
MT-4341 Elective Project	2	3	30
MT-4342 Seminar/Group Discussion	2	3	20
MT-4343 Training/Tour Viva-Voce	2	-	-
Total for Practicals	8	9	80
Total for Semester VII	**23**	**24**	**230**

PART IV, SEMESTER VIII

Subjects	Credits	Contacts hrs/week	Minimum contact hrs/Sem.
Theory:			
MT-4244 Energy and Environment in Metallurgical Industries	3	3	30
MT-4245 Advanced Processing Technologies	3	3	30
MT-4246 Industrial Management	4	4	40
MT-4247 to MT-4250 Elective II	3	3	30
Total for Theory	**13**	**13**	**130**
Practicals/Project:			
MT-4451 Modelling and Simulation	2	3	30
MT-4452 Elective Project	6	9	90
MT-4453 Comprehensive Viva-Voce	2	-	-
Total for Practicals	10	12	120
Total for Semester VIII	**23**	**25**	**250**
Total for Part IV	**46**	**49**	**480**
Grand Total for B.Tech. Programme	**199**	**221**	

Elective I (any one of the following)
MT-4136 Solid Waste Management
MT-4137 Alternative Routes of Iron and Steel Making
MT-4138 Cast Iron Technology
MT-4139 Nuclear Metallurgy

Elective II (any one of the following)
MT-4247 Alloy Design and Development
MT-4248 Electronic and Magnetic Materials
MT-4249 Automotive and Aerospace Materials
MT-4250 Surface Engineering

AM-2107 A COMPUTATIONAL METHODS (3 Credits)

Arithmetic at limited precision: Significant digits; absolute, relative, round-off and truncation errors; estimation of errors. Interpolation: Ordinary differences, operators E and D, divided differences; Lagrange's formula; central differences, formulae of Gauss, Bessel, Everett; splines; inverse interpolation. Method of least squares. Solution of algebraic and transcendental equations: Iterative methods, Newton-Raphson method; multiple roots. Solution of systems of linear equations: Elimination and relaxation methods, ill-conditioned systems. Computing the inverse matrix. Eigen values and eigen vectors, matrix decomposition. Numerical differentiation. Numerical integration: Gauss quadrature, Euler-Maclaurin series, asymptotic expansions, Newton-Cotes formulae, Romberg integration. Solution of ordinary differential equations: Methods of Runge-Kutta, Bulirsch-Stoer; Multi-step, multi-value and predictor-corrector methods. Solution of partial differential equations: Initial value and boundary value problems; Hyperbolic, parabolic and elliptic equations; Explicit and implicit methods; Stability analysis; Finite difference methods.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. S.S. Sastry: Introductory Methods of Numerical Analysis, Prentice-Hall of India.
2. F.B. Hildebrand: Introduction to Numerical Analysis, Tata McGraw-Hill.
3. S.C. Chapra and R.P. Canale: Numerical Methods for Engineers, 4^{th} edition, Tata McGraw-Hill.
4. W.H. Press, S.A. Teukolsky, W.T. Vetterling and B.P. Flannery: Numerical Recipes in C^{++}, The art of scientific computing, Cambridge.

MN -2107B MINERAL BENEFICIATION (3 Credits)

Ores and Minerals
Rocks, minerals, ores and gangue. Elementary ideas of formation of rocks and mineral deposits and their mode of occurrence and 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, filtration and drying.

Flow Sheets

Typical flow sheets for the benefication of coal and ores of copper, lead-zinc, iron and manganese with special reference to Indian deposits. Environmental problems.

Suggested Reading (Neither a necessary nor a sufficient requirement)

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

MT- 2101 PRINCIPLES OF EXTRACTIVE METALLURGY (3 Credits)

Introduction
Scope of extractive metallurgy, occurrence of metals in nature, minerals and ores. Elementary concepts of extraction of metals from their ores.

Pyrometallurgy
Ore preparation, drying and calcination, roasting, reduction of metal oxides, matte smelting and converting, metal refining processes: fire-refining, liquation and distillation.

Hydrometallurgy
Ore preparation, methods of leaching, bioleaching, solution purification and concentration: solvent extraction and ion exchange. Recovery of metals from leach solutions.

Electrometallurgy
Principles of electrolysis, electrolytic systems, elecrtrorefining and electrowinning.

Process Flow Sheets
Production of iron and steel, aluminium, copper, zinc and lead.

Primary metal production industries in India

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. J. Newton: Extractive Metallurgy, Wiley.
2. W.H. Dennis: Extractive Metallurgy- Principles and Applications, Pitman.
3. J.D. Gilchrist: Extraction Metallurgy, Pergamon.
4. R.D. Pehlke: Unit Processes in Extractive Metallurgy, Elsevier.
5. T. Rosenqvist: Principles of Extractive Metallurgy, McGraw Hill.
6. C.B. Gill: Nonferrous Extractive Metallurgy, Wiley-Interscience.
7. H.S. Ray and A. Ghosh: Principles of Extractive Metallurgy, New Age International.
8. H.S. Ray, R. Sridhar and K.P. Abraham: Extraction of Non-ferrous Metals, Affiliated East West.

MT- 2102 METALLURGICAL THERMODYNAMICS (4 Credits)

Basic Principles
Extensive and intensive properties, thermodynamic systems and processes. First Law of Thermodynamics, enthalpy, Hess' Law, heat capacity, Kirchhoff's law. Second Law of Thermodynamics, entropy, entropy change in gases, significance of sign change of entropy. Trouton's and Richard's rules. Driving force of a chemical reaction, combined statement of first and second laws of thermodynamics, Helmholtz and Gibbs free energies. Ellingham diagram, Equilibrium constants, van't Hoff's isotherm, Le Chatelier principle. Clausius-Clapeyron equation. Maxwell's equations, Third Law of Thermodynamics.

Solution Thermodynamics
Solution, mixture and compound. Raoult's law: activity, ideal solution, standard state. Partial molar quantities, Gibbs-Duhem equation, chemical potential, fugacity, activity and equilibrium constant. Free energy of mixing, excess and integral quantities. Regular solutions, α-function. Dilute solutions: Henry's and Sievert's laws. Alternative standard states. Gibbs-Duhem integration

Statistical concept of entropy. Elements of Gibbs Phase Rule and its applications.

Experimental Techniques
Determination of thermodynamic quantities by different techniques, viz. calorimetry, chemical equilibria, vapour pressure and electrochemical: aqueous, fused and solid electrolytes; formation, concentration and displacement cells.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. D.R. Gaskell: Introduction to Metallurgical Thermodynamics, McGraw-Hill.
2. L.S. Darken and R.W. Gurry: Physical Chemistry of Metals, McGraw-Hill.
3. G.S. Upadhyaya and R.K. Dube: Problems in Metallurgical Thermodynamics and Kinetics, Pergamon.
4. J. Mekowiak: Physical Chemistry for Metallurgists, George Allen & Unwin.
5. J.J. Moore: Chemical Metallurgy, Butterworths.
6. R.H. Parker: An Introduction to Chemical Metallurgy, Pergamon.

MT-2103 STRUCTURE OF MATERIALS (4 Credits)

Crystal Geometry
Lattices, unit cells, indexing of directions and planes, Weiss zone law. Stereographic projection. Symmetry operations and their matrix representation. Crystallographic restriction. Euler's construction. Crystallographic and non-crystallographic point groups. Crystal systems. Internal symmetry. Space groups, subgroups and supergroups. Bravais lattices. Brief description of imperfections in crystals.

Crystal Chemistry
Close packing of equal spheres, structure of common elements, polytypes. Atomic size, voids in close packed structures, packing of unequal spheres. Solid solutions and their classification. Hume-Rothery rules. Theory of alloy phases. Intermetallic compounds, Electron, Laves' and Haegg's phases. Structure of ionic compounds. Pauling's rules. Introduction to amorphous materials, liquid crystals, quasicrystals, Fullerenes, nanotubes and nanostructured materials.

Electrons in Solids
Types of bonding and its effects on properties. Wave-particle duality, concepts of group and phase velocity, Schrödinger equation. Free electron theory of metals, density of states, Fermi energy, Fermi-Diract statistics. Tight binding approximation. Electrons in a periodic potential: Kronig-Penney model, band theory of solids, Fermi surfaces, Brillouin zones, Effective mass.

Applications of Electron Theories
Metals, Semiconductors, Insulators. Temperature dependence of conductivity in metals. Lattice vibrations, specific heat of solids, thermal conductivity, optical properties, Pauli paramagnetism and ferromagnetism.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. L.A. Azaroff: Introduction to Solids, Tata-McGraw Hill.
2. S.M. Allen and E.L. Thomas: The Structure of Materials, John Wiley & Sons.
3. C.S. Barret and T.B. Massalski: Structure of Metals, Pergamon.
4. R.E. Reed-Hill and R. Abbaschian: Physical Metallurgy Principles, PWS.
5. K.M. Ralls, T.H. Courtney and J. Wulff: Introduction to Materials Science and Engineering, Wiley Eastern.
6. R.E. Hummel: Electronic Properties of Materials, Springer.

MT-2104 MATERIALS TESTING (3 Credits)

Significance of Material Testing

Mechanical Testing

Hardness Types of hardness test, Principles of Brinell, Vickers and Rockwell hardness testing, their merits and limitations; Micro-and Nano-hardness testing.

Tensile Testing 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.

Other tests Notched bar and instrumented impact; compression, torsion, bend; Creep and fatigue tests, sheet metal formability tests.

Non-destructive Testing
Principles and application of liquid penetrant, magnetic particle, ultrasonic, eddy current, radiography, optical holography and acoustic emission inspection methods, their merits and limitations.

ASTM and Indian standards for different tests.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. G.E. Dieter: Mechanical Metallurgy, McGraw-Hill.
2. Tensile testing: ed. Patricia Han, ASM.
3. Hardness testing: ed. Howard E. Boyer, ASM.
4. Metals handbook, Ninth Edition, vol.8, Mechanical testing, ASM.
5. R. Halmshaw: Non-destructive testing, Edward Arnold.
6. W.J. McGonnagle: Non-destructive testing, Gordon and Breach.
7. Metals handbook, Ninth Edition, vol.17, Nondestructive Evaluation and Quality control, ASM.

MN-2307C MINERAL BENEFICIATION (Practical) (2 Credits)

Illustrative list of experiments

1. Identification of common ores and minerals
2. Crushing
3. Grinding
4. Sieve analysis
5. Magnetic separation
6. Jiggin
7. Tabling
8. Flotation
9. Sedimentation
10. Coal washing

MT-2305 PHYSICAL METALLURGY (Practical) (2 Credits)

Illustrative list of experiments

1. Construction and calibration of thermocouples
2. Thermal analysis and DTA
3. Electrical resistivity measurement
4. Dilatometry
5. Crack patterns in glass
6. Effect of flaws on strength of glass
7. Study of metallurgical microscope and special techniques of microscopy
8. Study of image analyser
9. Study of X-ray units and electron microscopes
10. Study of Auger electron spectroscope
11. Study of stereomicroscope
12. Stereographic projections
13. Dislocations in LiF

MT-2306 EXTRACTIVE METALLURGY (Practical) (2 Credits)

Illustrative list of experiments

1. Roasting of sulphides
2. Reduction of oxides
3. Smelting of sulphide/oxide ores
4. Leaching of oxide ores
5. Solvent extraction
6. Electrowinning
7. Cementation
8. Distillation
9. Equilibrium measurements

EE-2207D ELECTRICAL ENGINEERING (3 Credits)

Electrical circuits:
Network elements: Voltages and current sources; Kirchoffs voltage and current law; Loop and nodal analysis; Superposition theorem; Thevenin's theorem; Norton's theorem; Maximum power transfer theorem.
Sinusoidal steady state analysis: R, L&C elements; Power and power factor: Phasor diagram; Resonance; Mutual inductance and coefficient of coupling.
Three phase circuits: Line and phase relationship; Power measurement.

Electrical Machines:
Constructional features of static and rotating machines; Statically and dynamically induced EMF. Transformer: Principal of working; EMF equation; Equivalent circuit; Voltage regulation and efficiency; O.C., S.C. and direct load test; Autotransformer.
D.C.Machines: Constructional features of D.C generator and motor; No-load magnetization; External characteristics; D.C. motor-starting, speed torque characteristics, speed control, applications.
Induction Machines: Principal of operation; Constructional details; Torque-slip characteristics; starting and speed control.
Synchronous machines: Constructional features; Voltage regulation of alternator and its determination by synchronous impedance method; Synchronous motor-starting, V and inverted V-curves, applications.
Distribution of electrical power: Tariff calculation.
Electrical measurement: Introduction to indication instruments; Ammeter, voltmeter, wattmeter, energy meter.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. Kothari, D.P. and Nagrath, I.J., "Electrical Machines", Tata McGraw-Hill Publishing Co. Ltd., New Delhi.
2. Huges, E., "Electrical Technology", Orient Longman.
3. Vincent Del Toro, "Electrical Engineering Fundamentals", Prentice Hall, Inc.
4. Cotton, H., "Advanced Electrical Technology", Isaac Pitman & Sons.

MT-2207 FUELS AND REFRACTORIES (3 Credits)

Fuels
Classification of fuels, their merits and limitations.

Solid Fuels
Origin of coal, its types, properties, proximate and ultimate analysis, storage and reserves in India. Coal washing, preparation and blending methods. Applications of coal.
Coke making by beehive and by-product ovens. Modern practices of coke making. Principles of graphitisation and reactivity. Characterization of coal and coke.

Selection of reductant /fuel for Blast Furnace, DRI, COREX, Cupola and Pit Furnace.

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 gas and Water gas.

Refractories
Classification of refractories. Properties and applications of Fireclay, Silica, Chromite, Carbon/Graphite, Magnesite, Dolomite, Zirconia, Silicon Carbide, Sillimanite, Kyanite refractories.

Selection of Refractories: Blast Furnace, LD Converter, Electric Arc Furnace.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. O.P. Gupta: Elements of Fuels, Furnaces and Refractories, Khanna Publishers (Delhi).
2. Efficient Use of Fuel, HMSO (London).
3. J.D. Gilchrist: Fuels, Furnaces and Refractories, Pergamon.
4. D.N. Nandi: Handbook of Refractories, Tata McGraw-Hill.
5. J.H. Chestors: Steel Plant Refractories; United Steel Companies, Sheffield.
6. F.H. Norton: Refractories, McGraw-Hill.

MT-2208 ELECTROMETALLURGY AND CORROSION (3 Credits)

Applied Electrochemistry
Absolute and single electrode potentials. Standard and reference electrodes. Decomposition potential. Polarization, gas and metal over voltages. EMF and galvanic series. Exchange current density and Tafel equation. Factors influencing current and energy efficiencies.

Electrometallurgy
Theory of single-metal and alloy plating. Factors influencing nature and distribution of plating with specific examples.Testing of electrodeposits. Electroforming. Preparation of metal powders, Electroless plating. Anodizing. Electropolishing. Electromachining. Plating on non-conductors.

Corrosion and its prevention
Electrochemical principles of corrosion. Mixed potential theory. Passivity. Forms of aqueous corrosion. Stress corrosion cracking. Hydrogen embrittlment, corrosion fatigue. High temperature oxidation of metals and alloys, rate laws, kinetics and mechanisms. Methods of corrosion protection including inhibition, anodic and cathodic protection and coating.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. S. Glasstone: An Introduction to Electrochemistry, Van Nostrand.
2. F.A. Lowenheim: Electroplating, McGraw-Hill.
3. Satya Narain and R. Saran: An Introduction to Electrometallurgy, Standard Publishers.
4. C.L. Mantell: Electrochemical Engineering, McGraw-Hill.
5. J.C. Scully: The Fundamentals of Corrosion, Pergamon.
6. M.C. Fontana: Corrosion Engineering, McGraw -Hill.

MT-2209 PHASE DIAGRAMS (3 Credits)

Unary Systems
Thermodynamic fundamentals. Free energy-temperature-pressure diagrams. Condensed phase rule. Allotropy. Degree of transformation.

Binary Systems with Two Phase Equilibria
Computation of phase diagrams. Solution models. Free energy-composition diagrams. Isomorphous phase diagrams. Lever rule. Calculation of liquidus and solidus in ideal systems. Equilibrium diagrams for non-ideal solutions with moderate departures from ideality. Equilibrium and non-equilibrium solidification in isomorphous systems. Miscibility gap and chemical spinodal. Cu-Ni system.

Binary Systems with Three Phase Equilibria
Eutectic systems. Primary and eutectic solidification. Al-Si system. Eutectoid, monotectic and monotectoid systems. Peritectic systems. Solidification in peritectic systems. Cu-Zn system. Peritectoid, syntectic and metatectic systems.

Complex Phase Diagrams
Rules for construction of phase diagrams for complex systems. Metastability. Fe-Fe_3C system.

Ternary Systems
Representation. Isothermal and vertical sections. Ternary isomorphous and eutectic systems. Illustrative examples.

Experimental Determination of Phase Diagrams
Microscopy, x-ray diffraction, thermal analysis, dilatometry, electrical resistivity and magnetic methods.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. P. Gordon: Principles of Phase Diagrams in Materials Systems, McGraw-Hill.
2. A. Prince: Alloy Phase Equilibria, Elsevier.
3. F.N. Rhines: Phase Diagrams in Metallurgy, McGraw-Hill.
4. W. Hume-Rothery, J.W. Christian and W.B. Pearson: Metallurgical Equilibrium Diagrams, The Institute of Physics (London).
5. R.E. Reed-Hill and R. Abbaschian: Physical Metallurgy Principles, PWS.

MET-2210 METALLOGRAPHY TECHNIQUES (4 Credits)

Scope of metallography

Optical Microscopy
Abbe's criterion for resolving power, Raliegh's criterion, numerical aperture, empty magnification. Principles of construction for simple and compound microscopes. Important lens defects and their correction. Types of objective lenses and eyepieces. Principles of phase contrast, interference and polarized light microscopy, bright field and dark field contrast, photo-micrography.

Scanning Electron Microscopy
Construction and working principle of SEM. Signals used for image formation. Resolving power, magnification, depth of field, depth of focus, image contrast, electron channelling. Applications of SEM. Sample preparation.

Transmission Electron Microscopy
Resolving power and optimum resolution achievable, electron lenses and their defects, construction and operation of a modern transmission electron microscope, ray diagrams for bright field, dark field and selected area diffraction modes. Ewald's sphere construction, indexing of diffraction patterns, kinematical theory of image contrast of bends, thickness variations, grain boundaries, stacking faults, dislocations and coherent precipitates. Scanning Transmission Electron Microscopy, Sample preparation.

Special Microscopy Techniques
Scanning Tunneling Microscopy, Scanning Acoustic Microscopy, Atom Force Microscopy and Thermal Wave Microscopy.

Quantitative Metallography
Point, lineal and areal analysis for volume fraction and grain size. Image analysers.

X-ray Metallography
Production, properties and detection of x-rays, Laue and powder methods: intensity calculations, Lorentz-polarization, absorption, temperature and multiplicity factors. Application of x-ray diffraction to identification of Bravais lattices, calculation of lattice parameters, residual stresses and orientation determination.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. R.C. Gifkins: Optical Microscopy of Metals, Pitman.
2. P.J. Grundy and G.A. Jones: Electron Microscopy in the Study of Materials, Edward Arnold.
3. D.B. Williams and C.B. Carter, Transmission Electron Microscopy, Plenum Press.
4. Materials Characterization Techniques, (eds.) G. Sridhar, et al. National Metallurgical Laboratory, Jamshedpur.
5. B.D. Cullity: Elements of x-ray Diffraction, Addison-wesley.
6. R.E. Smallman and K.H.G. Ashbee: Modern Metallography, Pergamon.

MT-2211 MECHANICS OF DEFORMATION AND FRACTURE (3 Credits)

Elastic and Plastic Behaviour
Concepts of stress, strain, ductility and toughness.

Theory of Elasticity
Stress at a point, State of stress in two and three dimensions. Mohr's circle of stress. Stress tensor. Strain at a point. Mohr's circle of strain. Hydrostatic and deviator components of stress. Stress-strain relationships. Strain energy. Anisotropy of elastic behaviour. Plane stress and plane strain deformation.

Theory of Plasticity
Flow curve, Yield criteria, Yield locus, invariants of stress strain. Stress-strain relations.

Fracture Mechanics
Concept of failure, Cracks in solids, Stress concentration. Griffith criterion of brittle fracture, Crack propagation with plasticity. Linear Elastic Fracture Mechanics. Fracture toughness
Fracture toughness parameters: Crack extension force G, Plane strain fracture toughness K_{IC}, Crack Opening Displacement COD, J. integral, Dynamic fracture toughness K_{ID}, Fracture toughness in corrosive environments K_{1SCC}. Significance of R curve.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. G.E. Dieter: Mechanical Metallurgy, McGraw-Hill.
2. R.W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, Wiley.
3. M.A. Meyers and K.K. Chawla: Mechanical Behaviour of Materials, Prentice Hall.

MT-2412 METALLOGRAPHY PRACTICAL (2 Credits)

1. Sample Preparation for Metallographic Observation: To prepare a given sample and get acquainted with different steps in specimen preparation.
   (a) Ferrous (b) Non-ferrous alloys

2. To study the microstructure of various samples of steels and getting familiar with Fe-C phase diagram.
   (a) cast steel (b) low C steel (C~ 0.03%) (c) 0.2%C (d) 0.4%C
   (e) 0.8% (f) 1.3%C (g) stainless steel

3. To study the microstructure of various samples of Cast Irons (CI) varying in carbon content.
   (a) Hypoeutectic white CI (b) Hypereutectic CI (c) Ni-hard CI
   (d) Hypereutectic Grey CI (e) Nodular CI.

4. To study the macrostructure and microstructure of Al and Cu alloys.
   (a) Cu-Cast ingot (b) Al-Cast ingot (c) Al-welded structure
   (d) Al-Si alloy (unmodified) (e) Al-Si alloy (modified)

5. To study the signature of deformation in microstructure.
   (a) Cold extruded Cu (b) Annealed Cu (c) Hot extruded brass
   (d) Pure Zn (e) Compressed Bronze (f) Hot rolled super alloy.

6. To study the microstructure of some light and special materials.
   (a) Widmanstatten Pattern: Ti alloy (b) Cored cellular microstructure: Mg-Al-Zr alloy (c) Type metal: Pb-Sn alloy (d) Babbit metal: Sn-Sb alloy
   (e) Composite bearing (f) Cu-graphite composite (g) ZAMAC: Zn-Al-Mg alloy.

7. Photomicrography.

8. Quantitative Metallography
   (a) Grain size determination (b) Volume fraction of the phases.

9. Indexing of Debye-Scherrer powder X-ray diffraction patterns.

10. Indexing of electron diffraction patterns.

11. SEM observation of fractured samples.

MT-2413 MECHANCIAL TESTING PRACTICAL (2 Credits)

1. Examine the variation of BHN & MHN with applied load for given samples and determine the Meyer's constants.

2. Study the variation of VHN with applied load for given specimens.

3. Evaluate Rockwell hardness of the given samples using appropriate scales.

4. Perform tensile test of the round sample and determine the following parameters:
   (i) Modulus of Elasticity (ii) % elongation (iii) % RA
   (iv) 0.2% YS (v) UTS (vi) Fracture strength (vii) Uniform elongation
   Also, draw engineering stress-strain curves and true stress-strain curves. Determine work hardening parameters.

5. Perform tensile test of the 'flat' sample and determine the following parameters:
   (i) Modulus of Elasticity (ii) % elongation (iii) 0.2% YS
   (iv) UTS (v) Fracture strength (vi) Uniform elongation
   Also, draw engineering and true stress-strain curves. Determine work hardening parameters.

6. Determine the impact energy of given samples at different temperatures using charpy impact tester and comment on the DBTT obtained.

7. Determine the impact energy of given sample by Izod testing machine compare the results obtained by direct reading and by calculation.

8. Determine the Erichsen-Ductility values of given sheet specimens. Comment on the surface feature of domes.

9. Determine the work-hardening behaviour of given specimens by cold-rolling. Comment on the results obtained.

10. Study the phenomenon of strain ageing.

11. Demonstration Experiments
    (a) Universal testing machines-Tension, Compression and shear tests.
    (b) Fatigue
    (c) Creep

MT-2414 ELECTROMETALLURGY AND CORROSION (Practical) (2 Credits)

Illustrative list of experiments

1. Study of electrode potentials
2. Study of simple corrosion cells
3. Study of polarization and passivity
4. Study of corrosion rates
5. Oxidation of metals
6. Electropolishing
7. Throwing power of electrolytic baths
8. Anodizing
9. Chromium plating
10. Effect of current density on plating
11. Alloy plating
12. Electroless plating

MT-3115 PHASE TRANSFORMATIONS (3 Credits)

Atomic Movements
Diffusion, Fick's laws, mechanisms of diffusion, Kirkendall effect, concentration and temperature dependence of diffusion coefficient, Darken's equations, Matano method, intrinsic diffusivities, diffusion along dislocations and grain boundaries.

Nucleation and Growth
Homogeneous and heterogeneous nucleation, thermodynamic barrier for nucleation, nucleation rate. Structure and energy of interfaces. Strain energy and its effect on nucleation. Diffusion controlled and interface controlled growth mechanisms.

Solidification
Redistribution of solute during solidification, constitutional supercooling. Origin of cellular and dendritic structures, solidification at high undercooling, rapid solidification, zone refining, growth of single crystals.

Solid State Transformations
Classification. Overall transformation kinetics, precipitation reactions, spinodal decomposition, particle coarsening, cellular precipitation, eutectoidal transformation, order-disorder transformation. Characteristics of diffusionless transformations, crystallography and thermodynamics of martensitic transformation, bainitic and massive transformation.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. J.D. Verhoeven: Fundamentals of Physical Metallurgy, Wiley.
2. D.A. Porter and K.E. Easterling: Phase Transformations in Metals and Alloys, Chapman and Hall.
3. V. Raghavan: Solid State Phase Transformations, Prentice-Hall.
4. R.E. Reed-Hill and R. Abbaschian: Physical Metallurgy Principles, third edition, PWS, Boston.
5. G.A. Chadwick: Metallography of Phase Transformations, Butterworths.

MT-3116 MECHANICAL BEHAVIOUR OF MATERIALS (3 Credits)

Modes of Plastic Deformation
Mechanisms and crystallography of slip and twinning. Concept of critical resolved shear stress. Deformation of single crystals and polycrystals. Hall-Petch relationship.

Dislocation Theory
Types 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 mechanisms and yield point, strain ageing and work hardening phenomena.

Creep
Generation and analysis of creep and creep-rupture data. Dislocation and diffusion mechanisms of creep. Grain boundary sliding and migration. Deformation mechanism maps. Effect of metallurgical and test variables on creep and fracture. Superplasticity. Parametric methods for prediction of long time properties.

Fatigue
Fatigue testing methods and machines. Stress-controlled and strain-controlled fatigue. Analysis of cyclic stress-strain data. Mechanisms of fatigue crack nucleation and propagation.

Fracture
Modes and mechanisms of fracture. Ductile- to- brittle transition. Fractography. Environment-assisted fracture.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. G.E. Dieter: Mechanical Metallurgy, McGraw-Hill.
2. R.W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, John Wiley.
3. R.W.K. Honeycombe: The Plastic Deformation of Metals, Edward Arnold
4. D. Hull: Introduction to Dislocations, Pergamon.
5. F. Garofalo: Fundamentals of Creep and Creep Rupture in Metals, MacMillan.
6. M.A. Meyers and K.K. Chawla: Mechanical Behaviour of Materials, Prentice Hall.

MT-3117 NONFERROUS EXTRACTIVE METALLURGY (4 Credits)

Aluminium Bayer process: chemistry and practice. Hall-Heroult process: carbon anodes, theoretical principles, factors influencing the process, current and energy efficiencies. Purification of aluminium. Alternative processes of aluminium production.

Copper Principles and methods of roasting, matte smelting, converting, fire-refining and electro-refining. Single-step and continuous copper production processes. Hydrometallurgy of copper.

Zinc Routes of zinc production. Pyrometallurgy of zinc: principles and practice of roasting, sintering and smelting. Hydrometallurgical extraction: roasting, leaching, electrolytic purification, electro-winning, residue treatment.

Lead Principles and practice of blast furnace smelting. Pyrometallurgical refining of lead bullion. Direct smelting practices.

Nickel Pyrometallurgical processing of sulphide concentrate. Winning of nickel from its oxide ores by various methods.

Magnesium Pidgeon and Magnetherm processes. Production of anhydrous $MgCl_2$ from sea water and magnesite. Electro-winning practice.

Gold Cyanidation process. Carbon-in-pulp process. Refining of gold.

Titanium Treatment of beach sand, upgradation of ilmenite. Chlorination of titania. Kroll process. Consolidation and refining.

Uranium Acid and alkali processes for digestion of uranium ores. Production of reactor grade UO_2 and massive uranium.

Secondary Metals

Present status and future prospects of nonferrous metal production in India (1)

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. K. Grjotheim and B.J. Welch: Aluminium Smelter Technology, Aluminium-Verlag.
2. A.R. Burkin (ed.) : Production of Aluminium and Alumina, Wiley.
3. A.K. Biswas and W.G. Davenport: Extractive Metallurgy of Copper, Pergamon.
4. S.W.K. Morgon: Zinc and its Alloy, Mac Donald and Evans.
5. A.R. Burkin (ed.): Extractive Metallurgy of Nickel, Wiley.
6. C.D. Harrington and AE. Reuhle : Uranium Production Technology, Van Nostrand.
7. A.N. Zelikman, O.E. Krein and G.V. Samsonov : Metallurgy of Rare Metals, Israel program for Scientific Translation.
8. H.S. Ray, R. Sridhar and K.P. Abraham: Extraction of Non-Ferrous Metals, Affiliated East - West.
9. N.Sevryukov, B. Kuzumin and Y. Chelishchev: General Metallurgy, Mir.

MT-3118 IRON MAKING (4 Credits)

Historical Development

Raw Materials
Iron ore types and properties: Strength, reducibility, swelling and softening tests.
Prepared - Ore Feed: Pellet and sinter making.
Reductant types and properties: Coke reactivity and strength after reaction.
Fluxes: types and properties.

Reduction Mechanism of Iron Ore

Blast Furnace
Construction, charging, burden distribution, thermal and chemical profile. Reactions in shaft, bosh and hearth. Hot metal composition control.
Modern Practices: High top pressure, fuel injection, oxygen enrichment, humidification and use of pre-reduced burden.
Blast furnace operations and irregularities. Gas cleaning. Hot blast stove. Pig casting. Instrumentation.

Alternate Methods of Iron Making
Need and classification. Coal based rotary kiln and Gas based shaft method of DRI production. DRI storage.
Principles of smelting reduction; COREX process. Mini blast furnace. Scope of renewable energy.

Ironmaking Industries in India

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. A.K. Biswas: Principles of Blast Furnace Iron Making, SBA.
2. J.H. Straussburger (ed.): Blast Furnace - Theory & Practice. Vols 1&2, Gordon & Breach.
3. R.H. Tupkary: Introduction to Modern Iron Making, Khanna Publishers.
4. S.S. Gupta and Amit Chatterjee: Blast Furnace Iron making, SBA, New Delhi.
5. Amit Chatterjee, R. Singh and B. Pandey: Metallics for Steelmaking-Production and use, Allied Publishers.
6. H. E. McGannon (ed.): The Making, Shaping and Treating of steel, United States Steel.
7. G.R. Bashforth: The Manufacture of Iron and Steel, Vol.1, Chapman and Hall.

MT-3119 FOUNDRY METALLURGY (3 Credits)

Introduction
Present status and future scope.

Moulds and Moulding Materials
Patterns: Functions, classification, allowances and materials. Core:
Functions, materials and preparation.
Moulds: Types and role of moulding sands, binders and additives. Mould compaction and bonding mechanism.

Casting Processes
Classification, moulding and casting processes: Green, Dry, Shell, Cold and Hot box, Silicate bonded, Investment, Full and Vacuum sealed, Squeeze, Rheo- and Compo-casting.
Die and centrifugal casting.

Melting and Casting Processes
Principles of Shaft, Hearth and Crucible melting. Cupola and its developments.
Design of Gating and Risering systems.

Solidification
Cast structure and its control, Segregation and Shrinkage.

Foundry Practice
Types of cast iron. Foundry practice of cast irons, steels, aluminium, copper and their alloys, Casting defects, Inspection and salvaging. Computer applications in foundries.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. P.D. Webster (ed), Fundamentals of Foundry Technology, Port Cullis Press.
2. H.F. Taylor, M.C. Flemings and J. Wulff, Foundry Engineering, Wiley.
3. R.W. Heine, C.R. Lopper and P.C.Rosenthal, Principles of Metal Casting, Mc Graw-Hill.
4. G.J. Davies, Solidification and Casting, Applied Science.
5. P.R. Beeley, Foundry Technology, Butterworths.
6. V. Kondic, Metallurgical Principles of Foundry, Edward Arnold.

MT-3120 INSTRUMENTAL ANALYSIS (4 Credits)

Basic Electronics: Semiconductor Diode-Characteristics and load line. Half-wave and full-wave rectifiers. Filters and power supplies.

Amplifying devices and their characteristics. Single and Multistage RC Coupled Voltage Amplifiers, High input impedance circuits, oscillators, operational amplifiers and it's applications.
Multi-vibrators, Counters and Logic gates.

X-ray and Electron Analytical Methods
X-ray fluorescence analysis (XRF), X-ray absorption analysis (XAS), Electron probe microanalysis (EPMA), Energy dispersive spectroscopy (EDS), Wavelength dispersive spectroscopy (WDS), Electron energy loss spectroscopy (EELS), Secondary ion mass spectroscopy (SIMS), Auger electron spectroscopy (AES), X-ray photoelectron spectroscopy, Raman spectroscopy.

Physico-chemical Methods

Spectrochemical Analysis: Atomic emission spectrography. Atomic absorption spectrography. Spectrophotometers and colorimeters.

Electro-analytical Techniques: Polarography, Electrogravimetry, Conductometry and Potentiometry.

Chromatographic Analysis: Gas chromatography.
Determination of non-metals by combustion and vacuum fusion analysis.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. L.E. Murr: Electron and Ion Microscopy and Microanalysis - Principles and Applications, Marcel Dekker.
2. C.R. Brundle and A.D. Baker: Electron Spectroscopy, Vol.l-3, Academic.
3. A.I. Vogel: Text book of Quantitative Inorganic Analysis, ELBS Longman.
4. H.H. Willard et.al.: Instrumental Methods of Analysis, CBS.
5. B.K.Sharma: Instrumental Methods of Chemical Analysis, Goel.
6. Materials Characterization Techniques, (eds.) G. Sridhar et.al. NML, Jamshedpur.

MT-3321 COMPUTER APPLICATIONS (Practical) (2 Credits)

Illustrative list of experiments

1. Introduction to computers: Hardware and essential software.
2. Algorithms and flow charts.
3. Solution of linear systems of equations.
4. Solution of nonlinear/transcendental systems of equations.
5. Numerical differentiation and integration.
6. Linear least squares analysis.
7. Curve fitting.
8. Computation of phase diagrams.
9. Calculation of stereographic projections.
10. Analysis of tensile test data.

MT-3322 FERROUS METALLURGY (Practical) (2 Credits)

Illustrative list of experiments

1. Study of raw materials for iron and steel making.
2. Testing of iron ore.
3. Testing of coal and coke.
4. Testing of refractories.
5. Sintering of iron ore.
6. Pelletisation of iron ore fines.
7. Reduction and swelling studies of iron ore.
8. Conversion of liquid pig iron into steel by oxygen blowing.
9. Ingot solidification.
10. Hot rolling studies.

MT-3323 FOUNDRY METALLURGY (Practical) (2 Credits)

Illustrative list of experiments

1. Size and shape analysis of foundry sands.
2. Effect of size and size distribution of sand on green sand properties.
3. Moisture and clay determination.
4. Effect of moisture and clay on the properties of green sand mould.
5. Study of dry moulding sand properties.
6. Study of high temperature properties of moulding sand.
7. Study of shell moulding, low pressure die casting and centrifugal casting.
8. Study of different casting defects.
9. Hand moulding and preparation of Al-base, Cu-base, and Pb-base alloy castings.
10. Machine moulding and preparation of ferrous casting.
11. Preparation of alloys with the help of master alloys.
12. Grain refinement of metals and alloys.
13. Modification of Al-Si alloys.
14. Melting and inoculation of cast irons.

MT-3224 HEAT TREATMENT (4 Credits)

Fundamentals
Fe-C equilibrium diagram. Isothermal and continuous cooling transformation diagrams for plain carbon and alloy steels. Microstructure and mechanical properties of pearlite, bainite and martensite. Austenitic grain size. Hardenability, its measurement and control.

Processes
Annealing, normalising and hardening of steels, quenching media, tempering. Homogenisation. Dimensional and compositional changes during heat treatment. Residual stresses and decarburisation.

Surface Hardening
Case carburising, nitriding, carbonitriding, induction and flame hardening processes.

Special Grade Steels
Stainless steels, High speed tool steels, Maraging steels, HSLA.

Cast irons
White, gray and S.G. irons

Nonferrous Metals
Annealing of cold worked metals. Recovery, recrystallisation and grain growth. Heat treatment of aluminium, copper, magnesium, titanium and nickel alloys. Temper designations for aluminium and magnesium alloys.

Controlled Atmospheres
Oxidizing, reducing and neutral atmospheres.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. R.E. Reed-Hill and R. Abbaschian: Physical Metallurgy Principles, PWS Publishing Company, Boston, Third Edition.
2. Vijendra Singh: Heat treatment of Metals, Standard Publishers Distributors, Delhi.
3. Anil Kumar Sinha: Physical Metallurgy Handbook, McGraw-Hill Publication.
4. R.C. Sharma: Principles of Heat Treatment of Steels, New Age International (P) Ltd. Publisher.
5. Charlie R. Brooks: Heat Treatment: Structure and Properties of Nonferrous Alloys, A.S.M. Publication.

MT-3225 MECHANICAL WORKING (3 Credits)

Fundamentals
Hot, warm and cold working. Role of temperature, strain rate and friction in metal working. Effect of working on structure and properties of metals and alloys. Texture and fibering. Workability test.

Rolling
Classification of rolling mills. Forces and geometrical relationships in rolling. Theories of hot and cold rolling. Calculation of rolling load and power. Soaking pits and reheating furnaces. Rolling of blooms, billets, slabs and flat products. Rolling mill equipment. Elements of roll pass design for rolling of structural sections, bars and rails. Defects in rolled products.

Other Processes
Principles, equipment and manufacturing methods: forging, extrusion, wire drawing and tube making. Elementary theories and calculation of working load and power. Sheet metal working operations. Forming limit diagrams.

Special Working Processes
Superplastic forming, High energy rate forming and Controlled rolling.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. G.E. Dieter: Mechanical Metallurgy, McGraw-Hill.
2. The Making, Shaping and Treating of Steel, U.S., H E. McGannon (ed.).
3. J.N. Harris: Mechanical working of Metals - Theory and Practice, Pergamon.
4. Metals Handbook, Ninth Edition, Vo1.l4, Forming and Forging, ASM.
5. S. Kalpakjian and S.R. Schmid, Manufacturing Processes for Engineering Materials, Pearson.

MT- 3226 STEEL MAKING. (4 Credits)

Historical Developments

Basic Principles
Physical chemistry of carbon, silicon, manganese, phosphorus and sulphur reactions. Control of nitrogen and hydrogen in steel. Deoxidation.

Basic Oxygen Steel Making
Principle, vessel design, and refractory lining. Lancing nozzles and jet-bath interaction. Raw materials and operating practices: charging, blowing, turndown, corrective practices and tapping. Blowing practices: AOD, VOD, VOAD and LD-AC.

Electric Steel Making
Arc and Induction furnace: merits and limitations.
Electric Arc furnace: mechanical and electrical components, transformer rating and furnace capacity, refractory practices. Raw material selection and melting practice.
Induction furnace: principle, type, construction, refractory lining and melting practice.

Alloy Steels and Ferro-Alloys
High carbon steels. Stainless steel by EAF and LD route. Tool steel.
Ferro alloys: Fe-Si, Fe-Cr, Fe-Mn.

Secondary Steel Making
Clean steel practice: Vacuum Induction Melting (VIM), Vacuum Arc Re-melting (VAR), Electroslag Re-melting (ESR)

Pit side practice and Continuous casting

Indian and world steel production scenario

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. J.M. Gaines (ed.): BOF Steelmaking, Vols. 1&2, The Iron and Steel Society.
2. G.R. Bashforth: The Manufacture of Iron and Steel, Vol 2, Chapman & Hall.
3. H.F. Schrewe: Continuous Casting of Steel, Stahl-eisen.
4. F.P. Edneral: Electrometallurgy of Steel and Ferro-alloys, Vols. 1&2, Mir.
5. R.H. Tupkary: An Introduction to Modem Steel Making, Khanna Publishers.
6. H E. McGannon (ed.): The Making, Shaping and Treating of Steel, U.S.

MT- 3227 TRANSPORT PHENOMENA (3 Credits)

Introduction
Transport processes, Dimensional analysis.

Momentum Transfer
Steady and Unsteady flows, Overall mass, energy and momentum balance, Navier-Stokes equation, Newton's law, non-Newtonian fluids, Laminar flow in falling film, flow through conduits. Inviscid fluid flow, Viscous flow. Laminar and turbulent, boundary layer theory, Friction factor, Flow past immersed objects, packed and fluidized bed.

Mass Transfer
Steady state mass transfer and diffusion, molecular diffusion in gases, liquids, biological gels and solids. Unsteady state mass transfer under different conditions, mass transfer coefficient, diffusion through porous medium and capillaries. Boundary layer flow and turbulence in mass transfer. Simultaneous heat, mass and momentum transfer.

Heat Transfer
Conduction
Steady State: One Dimensional - Composite wall and cylinder, multi-dimensional differential heat balance, shape factor, graphical and numerical methods.
Unsteady State: Analytical solutions of one dimensional lumped heat capacity system, heat flow in semi-infinite solid, convection boundary conditions, Heisler chart solutions.

Convection
Natural and forced convection, overall heat transfer coefficient, Fouling factor, types of heat exchangers.

Radiation
Physical mechanism, radiation properties, shape factor, heat exchange between non-black bodies, infinite parallel planes, radiation shields, gas radiation.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. J.S. Szekely and N.J. Themelis: Rate Phenomena in Process Metallurgy.
2. C.J. Geankoplis, Transport Processes: Momentum, Heat and Mass.
3. J.R.Welty, C.E. Wicks and R.E. Wilson: Fundamentals of Momentum, Heat and Mass Transfer.
4. J.P. Holman: Heat Transfer.
5. R.B. Bird, W.E. Stewart and J.F. Lightfoot: Transport Phenomena.

MT-3228 FUNDAMENTALS OF METALLURGICAL PROCESSES (3 Credits)

Thermodynamics of Multicomponent Systems
Dilute solutions and alternative standard states, activities and interaction coefficients in multicomponent systems and ionic melts.

Slags
Structure, properties and ionic theories, ferrous and nonferrous slags, basicity, state of oxidation, activity of ferrous oxide and liquidus isotherms in CaO-FeO-SiO_2 system, isoactivity lines, sulphide capacity.

Application of Thermodynamic Principles
Pyrometallurgy: Construction and applications of Kellogg diagrams in selective roasting of sulphides. Applications of Ellingham diagrams-nomographic scales in reduction, smelting and refining under standard and nonstandard conditions.

Hydrometallurgy: Stability limit of water, construction and applications of Pourbaix diagrams in leaching, role of pH in metal extraction and gaseous reduction with suitable examples.

Kinetics
Arrhenius equation, activation energy, homogeneous and heretogeneous reactions, order and molecularity of reactions, adsorption, chemisorption, kinetics of bimolecular gas-solid reactions: Langmuir-Hinshelwood and Langmuir-Rideal mechanisms, collision theory, absolute reaction rate theory, applications to gas-solid reactions, kinetics of iron ore reduction.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. L. Coudurior, D.W. Hopkins and I. Wilkomirstey: Fundamentals of Metallurgical Processes, Pergamon.
2. R.H.Parker: An Introduction to Chemical Metallurgy, Pergamon.
3. T.Rosenqvist: Principles of Extractive Metallurgy, McGraw-Hill.
4. J.J. Moore: Chemical Metallurgy, Butlerworths.
5. F. Habashi: Principles of Extractive Metallurgy, Vol.2, Hydrometallurgy, Gordon and Breach.
6. K.J. Laidler: Chemical Kinetics, McGraw-Hill.

MT-3429 HEAT TREATMENT (Practical) (2 Credits)

Illustrative list of experiments

1. Influence of cooling rate on the microstructure and hardness of plain carbon steels.
2. Effect of temperature on austenitic grain size.
3. Tempering characteristics of steels.
4. Jominy end-quench test.
5. Surface hardening of steel.
6. Isothermal transformation characteristics of an alloy steel.
7. Annealing of a cold worked metal.
8. Heat treatment of high speed steels.
9. Heat treatment of cast irons.
10. Age hardening of aluminium alloys.
11. Heat treatment of copper alloys.
12. Heat treatment of titanium alloys.

MT-3430 TRANSPORT PHENOMENA (Practical) (2 Credits)

Illustrative list of experiments

1. Unsteady state heat transfer with internal resistance.
2. Heat transfer by free convection.
3. Response time of thermocouple.
4. Cooling of ladle.
5. Pressure drop in packed bed.
6. Fluidisation.
7. Terminal velocity of particles and droplets.
8. Orifice meter.
9. Flow through a packed bed.
10. Emissivity determination.

MT-4132 MODELLING AND SIMULATION (3 Credits)

Review of Computational Methods
Solution of ordinary differential equations: Initial value and boundary value problems, Runge-Kutta (RK), Bulirsch-Stoer and Shooting methods.
Solution of partial differential equations: Initial value and boundary value problems, Hyperbolic, parabolic and elliptic equations, Explicit and implicit methods, Finite difference methods.

Modelling
Classification, functions, limitations and interrelationship of different types of models. Types and development of mathematical models. Development of rigorous and semi-rigorous physical models.

Simulation
Survey of simulation techniques. Molecular dynamics and Monte-Carlo simulations. Fuzzy logic, neural networks and genetic algorithms.

Applications
Materials behaviour and metallurgical processes.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. W.H. Press, S.A. Teukolsky, W.T. Vetterling and B.P. Flannery: Numerical Recipes in C^{++}- The art of scientific computing, Cambridge.
2. S.C. Chapra and R.P. Canale: Numerical Methods for Engineers, 4^{th} edition, Tata McGraw-Hill.
3. J.S. Szekely, J.W. Evans and J.K. Brimakombe: The Mathematical and Physical Modelling of Primary Metals Processing Operations, Wiley.
4. R.J. Arsenault, J.R. Beeler, Jr. and D.M. Esterling (Eds.): Computer Simulation in Materials Science, ASM.
5. I.M. Sibol: The Monte-Carlo method, Little Mathematics Library, Mir.
6. S. Rajasekaran, G.A.V. Pai: Neural networks, Fuzzy Logic and Genetic Algorithms-Synthesis and Applications, Prentice-Hall of India.

MT- 4133 MATERIALS FABRICATION TECHNOLOGY (3 Credits)

Metal Joining

Definition and principles of welding, brazing and soldering.
Classification of welding processes: fusion and solid state, consumable and non-consumable, flux and gas.
Types of joints. Positions of welding. Types and role of fluxes and gases.
Heat-affected-zone. Principles and working of oxyacetylene, shielded metal, submerged arc, gas metal, gas tungsten, resistance and friction welding processes.
Weldability. Welding of steels, cast irons and aluminium.
Defects and testing of welds.

Powder Metallurgy

Scope, advantages and limitations.
Powder Production: Chemical reaction and decomposition; atomization of liquid metals; electrolytic deposition, mechanical methods.
Powder Characteristics: Composition, structure, size, shape, surface topography, area, apparent and tap density, flow rate, compressibility, pyrophorocity and toxicity.
Compaction Methods: Die, isostatic and continuous compaction. Effect of compaction variables; pressure, speed, particle characteristics and lubrication.
Sintering: Mechanisms, variables. Liquid phase sintering. Hot and warm pressing.
Production of P/M Products: Bearings, filters, sintered carbides, magnetic materials, electrical contact materials, refractory materials and cermets.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. A.C. Davies: Science & Practice of Welding, Cambridge.
2. H.B. Carry: Modern Welding Technology, Prentice Hall.
3. L.M. Gourd, Principles of Welding Technology, 3rd Edition, Viva Books.
4. J.S. Hirschorn: Introduction to Powder Metallurgy, American Powd. Met. Inst.
5. R.H.T. Dixon and A. Clayton: Powder Metallurgy for Engineers, Brighton.
6. V.S. Arunachalam and O.V. Roman (eds.): Powder Metallurgy-Recent Advances, Oxford & IBH.

MT- 4134 MATERIALS SELECTION AND DESIGN (3 Credits)

Alloy Design
Brief history. Factors affecting alloy design. Methodology for alloy design for strength, toughness, and improved resistance to fatigue, creep, environment assisted fracture, corrosion, oxidation, wear and friction.

Materials Selection
Methodology of materials selection. Identification of required properties and materials index parameters based on elastic, yield, fracture, fatigue and creep limited design. Selection of materials based on available property data and optimisation to select the best material.

Illustrative Case Studies of Components and Materials
Pressure vessels, turbine blades, boiler tubes, oil/gas pipe lines, bearings, gears, springs and prosthetic materials.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. M.F. Ashby and R.H. Jones: Engineering Materials, Vol. 1&2 Pergamon.
2. J.K. Tien and G.S. Ansell (eds.): Alloy and Microstructural Design, Academic.
3. S. Ranganathan, V.S. Arunachalam and R.W. Cahn: Alloy Design, Indian Academy of Sciences.
4. F.B. Pickering: Physical Metallurgy and Design of Steels, Applied Sciences.
5. Materials Selection and Design, ASM Handbook, Vol. 20.

MT-4135 NON-METALLIC MATERIALS (3 Credits)

Introduction
Definition and classification of materials, comparison of properties of metals and nonmetallic materials. Nature of bonding.

Ceramics
Structure, defects. Powder processing and consolidation. Glasses and glass-ceramics, glass fibres.
Structural ceramics: fracture toughness, toughening mechanisms. Electro-optic, dielectric, ferroelectric, piezoelectric, magnetic, superconducting and laser ceramics.

Polymers
Structure, properties and applications of thermoplastics and thermosets. Conducting polymers and bio-degradable polymers.

Composites
Prepration, properties and applications of metal-matrix, ceramic - matrix and polymer - matrix composites. Advanced composites. Deformation and fracture behaviour of composites.

Semiconductors
Structure, properties, preparation and applications of intrinsic and extrinsic semiconductors.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. W.D.S. Kingrey: Introduction to Ceramics, John Wiley.
2. W.S. Smith: Principles of Materials Science and Engineering, McGraw-Hill.
3. V. Raghavan: Materials Science and Engineering, Prentice-Hall.
4. M.F. Ashby and D.R.H. Jones: Engineering Materials Vol.2, Pergamon.
5. J.F. Shakelford: Materials Science for Engineers, McMillan.
6. K.K. Chawla: Composite Materials Science and Engineering, Springer.
7. N. Chawla and K.K. Chawla: Metal Matrix Composites, Springer.

Elective I (MT 4136 - 4139)

MT- 4136 SOLID WASTE MANAGEMENT (3 Credits)

Solid Wastes
Sources, types and characteristics.
Present disposal techniques used by iron and steel, aluminium, copper, lead, zinc, gold and uranium Industries and Related hazards.
Land filling: site selection, filling operation, leachate in land fills, safe storage techniques.
Scope of converting solid waste into value added products.

Processing
Basic principles of comminution and sizing techniques.

Pelletisation: Principle, equipments, hardening mechanism, firing system, characterization and use.

Sintering: Principle, technique, process parameters, testing and use.

Briquetting: Principle, process types and use.

Utilisation

Mine waste, BF slag, SMS slag, Red mud, Fly ash, Gold slime and Uranium waste.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. Y.V.Swamy et.al. (ed.): Management of Industrial Effluents and Waste, Allied Publishers.
2. R.C. Gupta (ed.): Proc. Environmental Management in Metallurgical Industries, Allied Publisher.
3. H.S. Peavy et al: Environmental Engineering, McGraw- Hill.
4. B.F. Ball et al: Agglomeration of Iron Ores, Elsevier.
5. K.Meyer: Pelletisation of Iron Ores, Springer.
6. W.A. Knepper (ed.): Agglomeration, Wiley Interscience.

MT-4137 ALTERNATIVE ROUTES TO IRON & STEEL MAKING (3 Credits)

Introduction
Need for the development of alternative routes, approaches towards new techniques. Classification of processes.

Principles
Thermodynamic and kinetic aspects of iron ore reduction in solid and liquid state using solid/gaseous reductants.

Methods
Sponge iron production using shaft, kiln, retort and rotary hearth reactors. Raw materials preparation. Selection of reductants. Heat and mass transfer. Energy consumption and operating problems. Storage, transportation and utilization of sponge iron in India.

Pre-Reduced Pellets and Powders
Pre-reduced iron ore pellets for blast furnace applications, concept of composite pellets and its feasibility. Iron powder and iron carbide preparation from fluidised bed reactor and other processes. Operating/storage problems.

Smelting-Reduction Processes
Principles, classification, merits and limitations. COREX process and electric smelting processes.

Steel Making
Continuous and direct steel making.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. L.Von Bogdandy and H.J. Engell: Reduction of Iron Ores, Springer.
2. R.R. Rogers (ed.): Proc. of Symp. Iron Ore Reduction, Pergamon.
3. Proc. of Int. Conf. on Alternative Routes to Iron & Steel under Indian Conditions, IIM Jamshedpur 1988.
4. A. Chatterjee, R. Singh and B. Pandey: Metallics for Steelmaking-Production and Use, Allied Publisher.

MT-4138 CAST IRON TECHNOLOGY (3 credits)

Introduction
Cast Iron family.

Melting furnaces
Classification, melting practice and selection of a melting unit.

Grey Cast Irons
Structure and solidification behaviour. Graphite morphology, effect of variables on properties of grey irons. Casting design, melting, gating and risering practice. Theory and practice of inoculation. Heat treatment and applications.

Malleable Cast Irons
Types, special properties and uses, white iron foundry practice. Theory and practice of white heart and black heart malleablization, pearlitic malleable irons.

S.G. Cast Irons
Types, special characteristics and applications. Melting and casting practice. Post-inoculation treatments, solidification behaviour and heat treatment.

Special Cast Irons
Vermicular graphitic, high strength, corrosion and heat resistant cast irons. Alloy cast iron.

Inspection
Metallurgical inspection, quality control and salvaging of cast irons.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. H.T. Angus: Cast Iron-Physical and Engineering Properties, Butterworths.
2. J. Laing and R.T. Rolfe: Mannual of Foundry Practice for Cast Irons, Chapman and Hall.
3. Metals Hand Book, 9th edition, Vol.15, Casting, ASM.
4. R. Elliott: Cast Iron Technology, Butterworths.

MT-4139 NUCLEAR METALLURGY (3 Credits)

Nuclear Structure
Structure of the nucleus, binding energy, fission reactions, neutron cross sections, moderation of neutrons, multiplication factor. Fusion reactions.

Reactors and Materials
Classification of nuclear reactors. Materials for nuclear reactors viz., fuels, moderators, control rods, coolants, reflectors and structural materials. Fabrication of fuel and cladding materials.

Radiation Effects
Interaction of radiation with materials. Radiation hazards, safety and shielding. Uses of radioactive isotopes. Disposal of radioactive wastes.

Production of Nuclear Grade Materials
Atomic minerals, their occurrence in India, general methods of their processing. Production metallurgy of nuclear grade uranium, thorium, beryllium and zirconium. Production of enriched uranium. Processing of spent fuel and extraction of plutonium.

Reactors and Atomic Energy Programmes in India

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. R. Stephenson: Introduction to Nuclear Engineering, McGraw-Hill.
2. S. Glasstone and A. Sesonke: Nuclear Reactor Engineering, Van Nostrand.
3. T.J. Connolly: Foundation of Nuclear Engineering, Wiley
4. A.N. Zelikman, O.E. Krein and G.W. Samsonov: Metallurgy of Rare Metals, Israel Programme of Scientific Translation.
5. C.D. Harrington and A.E. Ruehle (eds.): Uranium Production Technology, Van Nostrand.
6. A.R. Cooper: Chemical Processing in the Atomic Energy Industry, Iliffe.

MT-4340 METAL FABRICATION AND NON-DESTRUCTIVE TESTING (Practical) (2 Credits)

Illustrative list of experiments

1. Oxy-acetylene welding of MS plate and aluminium.
2. Manual metal arc welding of MS plates with different types of joints.
3. Bead -on -plate welds by horizontal, vertical up and vertical down positions of welding.
4. Soldering of tin plates.
5. Brazing of brass plate.
6. Study of weld metal and HAZ microstructure.
7. Submerged arc welding.
8. Dye penetrant inspection.
9. Magnetic particle inspection.
10. Eddy current inspection.
11. Detection of flaws and measurement of thickness using ultrasonic methods.
12. Radiographic inspection.
13. Determination of flow rate and apparent density of powders.
14. Determination of (a) compressibility of powders (b) spring back and (c) ejection pressure of compacts.

MT-4244 ENERGY AND ENVIRONMENT IN METALLURGICAL INDUSTRIES (3 Credits)

Energy
Energy sources and their application in metal industry.
Mining, storage, transportation and usage of the energy source.
Green House effect: Problems and possible solutions.
Hydrogen and biomass as renewable energy sources.
Energy conservation in metal extraction, shaping and treating.

Environment
Waste generation Impact of metal industries on environment.
Solid wastes: Generation, hazards and disposal.
Liquid wastes: Types, sources, hazards and disposal.
Gaseous emissions: Types, sources and hazards of NO_x, SO_2, CO, SPM and fluorides.
Noise Emission: Sources and hazards.
Thermal Emission: Sources and hazards. Nuclear Wastes and disposal.

Environmental Laws and Standards

Suggested Reading (Neither a necessary nor a sufficient requirement)

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

MT-4245 ADVANCED PROCESSING TECHNOLOGIES (3 Credits)

Principles
Synthesis of novel microstructures. Solidification under local equilibrium, metastable phase selection, departures from local interfacial equilibrium. Thermal history and solute redistribution. Directional solidification. Metal foaming

Rapid Solidification
Splat quenching, melt spinning and planar flow casting techniques. Ideal and Newtonian cooling, estimation of cooling rate. Atomization and spray forming, undercooling techniques of materials synthesis. Stability of metastable microstructures. Consolidation of rapidly solidified materials: Hot pressing, hot extrusion and hot isostatic pressing.

Nanomaterials Processing
Vapour condensation, sol-gel, mechanical alloying, chemical processing, biomimetic processing, laser cladding, thermal and plasma spray coating techniques. Processes involving severe plastic deformation.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. M.C. Flemings: Solidification Processing, McGraw-Hill.
2. M. Cohen, B.H. Kear and R. Mehrabian (eds.): Rapid solidification Processing-Principles and Technologies, Vols 1 &2, Claitors.
3. T.R. Anantharaman and C. Suryanarayana (eds.): Rapid Solidification: Technology, Trans Tech.
4. V.S. Arunachalam and O.V. Raman (eds.): Powder Metallurgy- Recent Advances, Oxford and IBM.
5. P. Rama Rao: Advances in Materials and Their Applications, Wiley Eastern.

MT-4246 INDUSTRIAL MANAGEMENT (4 Credits)

Factory Planning
Types of industrial organisations. Organisational structures. Management functions and concepts. Plant location and layout. Materials Handling.

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. Production planning and control. Sales forecasting. Inventory control.

Project Management
Elementary concepts of operations research, networking: PERT and CPM. Concepts of quality control. Statistical quality control. Quality circles, TQM and Six sigma.. ISO Standards.

Personnel Management
Leadership and motivation. Work study: Time and motion. Wages and incentives.

Management Information Systems
Aims, characteristics, designs and implementation.

Entrepreneurship
Relevance and benefits. Essential qualities of an entrepreneur. Preparation of a project report. Feasibility study. Market survey. Agencies for financial and technical assistance.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. T.R. Banga and S.C Sharma.: Industrial Organisation and Engineering Economics, Khanna Publishers.
2. O.P Khanna: Industrial Engineering and Management, Dhanpat Rai and Sons..
3. C.B. Gupta and N.P Srinivasan.: Entrepreneural Development, S. Chand and Sons.
4. L.S Srinath.: PERT and CPM- Principles and Application, Affiliated East - West.

Elective II** (MT- 4247 to MT- 4250)

MT-4247 ALLOY DESIGN AND DEVELOPMENT (3 Credits)

Phase Stability and Microstructural Features
Phase stability, methods to evade phase diagram restrictions, effect of minor and trace elements. Definition and quantification of microstructural parameters. Control of size, distribution, shape and coarsening of second phase particles.

Strengthening and Toughening Mechanisms
Fibre strengthening. Toughening of brittle crystals. Enhancement of fracture toughness. Optimization of strength and toughness.

Design Rationale
Resistance against fatigue, creep, corrosion, hot corrosion, stress corrosion cracking and hydrogen embrittlement.

Alloy Development
Superalloys: Al alloys, Ti alloys, Ti aluminides and maraging steels.
Ni-free nitrogen stabilized stainless steels, HSLA steels and Interstitial free grade steels.
Alnico, high damping capacity alloys.
High strength bulk metallic glasses and nano-crystalline alloys.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. M.F. Ashby and R.H. Jones: Engineering Materials, vol. 1&2 Pergamon.
2. J.K. Tien and G.S. Ansell (eds.): Alloy and Microstructural Design, Academic.
3. S. Ranganathan, V.S. Arunachalam and R.W. Cahn: Alloy Design, Indian Academy of Sciences.
4. F.B. Pickering: Physical Metallurgy and Design of Steels: Applied Sciences
5. Materials Selection and Design, ASM Handbook, Vol. 20.

MT-4248 ELECTRONIC AND MAGNETIC MATERIALS (3 Credits)

Electronic Materials

Review of electron conduction in solids. Conductors, semiconductors and insulators. Hall effect. Temperature dependence of electrical conductivity. Thermal conductivity. Thermoelectric properties. Behaviour of metal-metal, metal-semiconductor, semiconductor-semiconductor junctions.

Semiconductor materials, direct and indirect band gap semiconductors. Semiconductor devices. Amorphous semiconductors and their applications. Opto-electronic and photonic materials.

Ionic conductivity. Superconductivity, superconducting materials and their applications. Dielectric, piezoelectric and ferroelectric materials: Applications in transducers and sensors.

Magnetic Materials

Introduction. Classification. Magnetic moments.

Soft magnetic materials: Ferrites, garnets, Fe-Si alloys, permalloy, superpermalloy and amorphous magnetic alloys. Hard magnetic materials: AlNiCo, barium hexaferrites. Applications of soft and hard magnetic materials.

Magnetic bubbles, rectangular loop ferrites, magnetic anisotropy, magnetostriction. Superparamagnets, giant and colossal magneto resistance materials.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. R.E. Hummel: Electronic Properties of Materials, Springer.
2. L. Solymar and D. Walsh: Lectures in the Electronic Properties of Materials, Oxford University Press.
3. V. Raghavan: Materials Science and Engineering, Prentice- Hall of India.
4. M.C. Lovell, A.J. Avery and M.W. Vernon: Physical Properties of Materials, ELBS.
5. L.I. Azaroff: Magnetic Materials.
6. S.O. Kasap: Principles of Electronic Materials and Devices, Tata McGraw-Hill.

MT-4249 AUTOMOTIVE AND AEROSPACE MATERIALS (3 Credits)

Introduction
Brief outline of the essential requirements of materials for automotive and aerospace applications.

Light Metals and Alloys
Processing, properties and applications: Aluminium alloys e.g. Al-Cu, Al-Si, Al-Cu-Mg, Al-Zn-Mg-Cu, Al-Li; titanium alloys e.g. alpha, near alpha, alpha beta and titanium aluminides; magnesium alloys with Cu, Zn, Zr and rare earth elements.

Superalloys
Classification and development of superalloys. Physical and mechanical properties; heat treatment, microstructures and strengthening mechanisms. Creep resistance. Oxidation and hot corrosion. Coatings. Processing developments and applications.

Steels
Heat treatment, microstructure, mechanical properties and typical applications of HSLA, dual phase, ultra low carbon, interstitial free, ultra high strength, cryogenic and maraging steels.

Composites and Metal Foams
Typical composites and their applications: Metal-matrix, fibre reinforced plastic and carbon-carbon composites. Metal foams and their application.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. I.J. Polmear: Light Alloys-Metallurgy of the Light Metals, Edward Arnold.
2. C.T. Sims and W.C. Hagel: The Superalloys, Wiley-Interscience.
3. F.B. Pickering: Physical Metallurgy and Design of Steels, Applied Science.
4. L.J. Broutman and R.H. Krock (eds.): Composite Materials, Academic press.

MT- 4250 SURFACE ENGINEERING (3 Credits)

Introduction
Material surfaces and their importance in tribology.

Friction
Fundamentals, types and measurement of solid, liquid and gaseous friction. Frictional heat and its estimation.

Wear

Modes of adhesive, abrasive, erosive, fretting, corrosive, erosive-corrosive, sliding, rolling, impact and lamination wear. Worn surface topography, debris analysis and wear mechanism maps.

Lubrication
Lubricants and additives, mechanism of solid, liquid and gaseous lubricants.
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Friction and wear
Bearings, pistons, cylinders, brakes, cutting tools, dies and electrical contacts.
Materials: Al-Si, Ti-alloys, Cemented carbides and metal -polymer and ceramic-matrix composites

Surface modification processes
Case-hardening, shot peening, chemical vapour deposition (CVD), physical vapour deposition (PVD), thermal barrier coatings, plasma deposition, sputter coating, laser processing, ion implantation, electro-and electroless-plating processes, surface cleaning and finishing processes. Testing and evaluation of surface coatings.

Suggested Reading (Neither a necessary nor a sufficient requirement)

1. A.D. Sarkar: Wear of Metals, Pergaman.
2 E. Rabinowiez: Friction and Wear of Materials, Wiley.
3. Properties of Metallic Surfaces: Institute of Metals.
4. Surface treatments for protection. The Institute of Metallurgists Series 3, No.10.
5. Friction, Lubrication and Wear Technology, Vol. 18, ASM, Handbook.

MT-4451 MODELLING AND SIMULATION (Practical) (2 Credits)

Development and execution of illustrative computer programs on C/C++ in the following topics.

1. Fuzzy logic.
2. Neural networks.
3. Genetic algorithms.
4. Simulated annealing.
5. Molecular dynamics simulations.
6. Monte Carlo simulations.
7. Computation of phase diagrams.
8. Finite difference method for heat conduction and solidification.
9. Finite element method for elasto-plastic deformation.