BRANCH-METALLURGICAL ENGINEERING

2nd Semester

***Specialization:*METALLURGICAL AND MATERIALS ENGINEERING**

Second Semester							
Theory					**Practical**		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Transport Phenomena in Metallurgy	4-0	4	100	50	-	-	-
Specialization Core-2 Mechanical Behavior of Materials	4-0	4	100	50	-	-	-
Elective I (Specialization related) 1.Solid State Phase Transformation 2.Mechanical Working of Materials 3.Physics of Materials 4.Process Metallurgy	4-0	4	100	50	-	-	-
Elective II(Departmental related) 1.Advanced Casting Processes 2.Metal Failure and Analysis 3.Industrial Heat Treatment 4.Nano Materials 5.Modeling and Computer Application in Metallurgy 6.Powder Metallurgy	4-0	4	100	50	-	-	-
Elective III (from any Department) 1.Tribology of Materials 2.Composite Materials 3.Bio Materials 4.Degradation of Materials	4-0	4	100	50	-	-	-
Lab-2 Material Processing and Process Metallurgy Lab					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

BRANCH-METALLURGICAL ENGINEERING

2nd Semester

Specialization: **INDUSTRIAL METALLURGY**

Second Semester							
Theory					**Practical**		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Metal Forming Theory and Practices	4-0	4	100	50	-	-	-
Specialization Core-2 Advanced Ferrous Production Technology	4-0	4	100	50	-	-	-
Elective I (Specialization related) 1.Non Ferrous Metal Extraction 2.Alternatives Routes of Iron Making 3.Mineral Engineering 4.Material Joining and Non Destructive Testing	4-0	4	100	50	-	-	-
Elective II(Departmental related) 1.Advanced Casting Processes 2.Metal Failure and Analysis 3.Industrial Heat Treatment 4.Nano Materials Modeling and Computer Application in Metallurgy	4-0	4	100	50	-	-	-
Elective III(from any department) 1.Tribology of Materials 2.Composite Materials 3.Bio Materials 4.Degradation of Materials	4-0	4	100	50	-	-	-
Lab-2 Fabrication and Characterisation of Materials Lab					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

DETAILED SYLLABUS OF SECOND SEMISTER M.TECH 2016-17 ADDMISSION BATCH

BRANCH-METALLURGICAL ENGINEERING

Specialization: **INDUSTRIAL METALLURGY**

Second Semester							
Theory					**Practical**		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Metal Forming Theory and Practices	4-0	4	100	50	-	-	-
Specialization Core-2 Advanced Ferrous Production Technology	4-0	4	100	50	-	-	-
Elective I (Specialization related) 1.Non Ferrous Metal Extraction 2.Alternatives Routes of Iron Making 3.Mineral Engineering 4.Material Joining and Non DestructiveTesting	4-0	4	100	50	-	-	-
Elective II(Departmental related) 1.Advanced Casting Processes 2.Metal Failure and Analysis 3.Industrial Heat Treatment 4.Nano Materials 5.Modeling and Computer Application in Metallurgy 6.Powder Metallurgy 7.Refractory	4-0	4	100	50	-	-	-
Elective III(from any department) 1.Tribology of Materials 2.Composite Materials 3.Bio Materials 4.Degradation of Materials	4-0	4	100	50	-	-	-
Lab-2 Fabrication and Characterisation of Materials Lab					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

Metal Forming Theory and Practices

Module-I (12 Hours)

Introduction:- Classification of Forming Processes, Mechanism of metal working, Flow-stress determination, Temperature in metal working, Strain-rate effect, Metallurgical structure, Friction and lubrication, Deformation-zone Geometry, hydrostatic pressure, Workability, residual stresses.

Module-II (16 Hours)

Classification of Forging Processes, forging in plane strain, Open-die forging, Closed-die forging, Forging loads in closed-die forging, forging defects, Residual stresses in forging.
Classification of Rolling Processes, Types of rolling mills, Hot rolling, Cold rolling, Rolling of bars and shapes, Forces and Geometrical relationships in rolling, Analysis of rolling loads: Rolling variables, Defects in rolled products, Rolling mill control, Theories of Cold-rolling and hot-rolling.
Classification of Extrusion Processes, Hot extrusion, Deformation, Lubrication and Defects in extrusion, Analysis of extrusion process, Cold extrusion and Hot forming, Hydrostatic extrusion, Extrusion of tubing, Seamless pipe.

Module-III (12 Hours)

Drawing of Rods, Wires and Tubes: Rod and Wire drawing, Analysis of wire drawing, Tube drawing, Analysis of tube drawing, Residual stresses in rod, wire and tubes.
Sheet-Metal Forming: Sheet metal forming methods, Shearing and blanking, Bending, Stretch forming, Deep drawing, Forming limit criteria, Defects in formed parts.
Types of Machining Operations, Advanced Metal Forming Processes: Details of high energy rate forming(HERF) process, Electro-magnetic forming, Explosive forming, Electro-hydraulic forming, Stretch forming, Contour roll forming.

Books for reference:

1. Dieter G. E., Mechanical Metallurgy, McGraw-Hill.
2. HertzbergR.W., Wiley J., Deformation and Fracture Mechanics of Engineering Materials.
3. MeyersM. A. and Chawla K. K., Mechanical Behaviour of Materials.
4. Courtney T.H., Mechanical Behaviour of Materials.
5. DeGarmoE. P., BlackJ. T and KohserR. A.,Materials and Processes in Manufacturing(8th Edition), Prentice Hall of India, New Delhi (ISBN 0-02-978760).
6.Ghosh A. and Mallik A.K., Manufacturing Science, Affiliated East-West Press Pvt. Ltd. New Delhi.
7. BenedictG.F. and Dekker M., Nontraditional Manufacturing Processes, Inc. New York (ISBN 0-8247-7352-7).

Advanced Ferrous Production Technology

Module I (16 Hours)

Blast furnace principles and practice for iron making: B.F.zone reactions, B.F profile, stove and gas cleaning units. Blast furnace slag: slag theory, formation of primary slag, bosh slag and hearth slag. Fe-C-O, Fe-O-H phase equilibrium. Material balance in B.F. iron making. Modern trends in blast furnace.

Principles of steel making reactions viz decarburization, dephosphorization, desulphurization, silicon & manganese reactions. Deoxidation of liquid steel: Requirement of deoxidizers, deoxidation practice, use of complex deoxidizers.

Module II (12 Hours)

LD Process: design of converter & lance, raw materials, operation, chemical reactions vizemulsion formation, dephosphorisation and decarburisation, Control: bath and slag composition, temperature and residual bath oxygen control. catch carbon technique, advancement in LD: Use of Sub lance, LDAC. OBM/Q-BOP process, concept, operation and modern trends of the process. Mixed/ combined blowing process and comparison with LD and OBM.

Module III (14 Hours)

Electric arc furnace: transformer capacity, secondary voltage, spacing of electrodes, advantages, charging, melting and refining practices for plain carbon and alloys steels. Advances in EAF: UHP electric arc furnace with DC supply.

Duplex processes of stainless steel making using VOD, AOD and CLU.

Physical chemistry of DR processes, HyL, SL/RN, Midrex and Fluidised bed Processes. SmeltingReduction Processes- COREX, INRED and FINEX.Use of DRI in arc furnaces and its effect on performance.

Books for reference:

1. Biswas A.K., Principles of Blast Furnace Iron Making, SBA.
2. Ghosh A., Chatterjee A., Ironmaking and Steelmaking Theory and Practices, PHI Pvt. Ltd.
3. Tupkary R.H.,Tupkary V. R., An Introduction to Modern Iron Making, Khanna Publishers
4. Tupkary R.H.,Tupkary V. R., An Introduction to Modern Steel Making, Khanna Publishers.
5. Bashforth G.R., The Manufacture of Iron and Steel, Chapman & Hall.
6. Edneral F.P., Electrometallurgy of Steel and Ferroalloys, Vol. 1&2, Mir.
7. Chatterjee A., Hot Metal Production by Smelting Reduction of Iron Oxide, PHI Learning Pvt. Ltd. New Delhi 2010
8. Rosenqvist T., Principles of Extractive Metallurgy, Tapir Academic Press, 2004

Non Ferrous Metal Extraction

Module I (12 Hours)
Extraction of metals from oxides and sulphides: thermodynamic principles, Ellingham diagrams, metallothermic reduction.
General methods of extraction:
Pyro-metallurgy: calcinations, roasting and smelting,
Hydrometallurgy: leaching, solvent extraction, ion exchange, precipitation, and
Electrometallurgy: electrolysis and electro-refining.

Module II (12 Hours)
Aluminium: Bayer's process and factors affecting its operation, Hall- Heroult process: Principle and practices, anode effect, refining of aluminium. Alternate methods of production of alumina and aluminium.
Copper: roasting of sulphides, matte smelting, converting; refining, by-products recovery; recent developments, continuous copper production processes, hydrometallurgy of Copper.
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.

Module III (12 Hours)
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, Th, Co, W and, Mo.

Books for Reference:
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. Rosenqvist T, Principles of Extractive Metallurgy, Tapir Academic Press, 2004.

Alternative Routes of Iron Making

Module I (12 Hours)
Characteristics of raw materials and their preparation. Thermodynamics and Kinetics aspects.
Direct Reduction Processes:
Reduction of Iron bearing materials in shaft furnace, rotary kiln, retort and fluidized bed with special reference to reductant, energy consumption and operational problems.

Module II (12 Hours)
Commercially available processes like SL/RN, ACCAR, Krup-CODIR, Kinglon Meter, MIDREX, HyL,
Purofer, Iron Carbide, etc.

Module III (12 Hours)
Uses of DRI in steel making, iron making and foundries; effect on DRI on EAF performance and product characteristics.
Smelting Reduction Processes:
COREX, ROMELT, Fluidized bed reactors, Hismelt etc. Present status of alternative methods of iron making in India.

Books for reference:
1. Chatterjee A., Alternative Routes of Iron Making, PHI.
2. Chatterjee A., Beyond the Blast Furnace.
3. Sarangi A., Sarangi B., Sponge Iron Production in Rotary Kiln, PHI.
4. Jerome Feinman& Donald R. Mac Rae,Editiors: Direct Reduction of Iron, Allied Publishers Ltd.

Mineral Engineering

Module I (14 Hours)
Introduction to mineral beneficiation, sampling, liberation studies and its importance. Comminution: Fundamentals of comminution, crushing -- construction and operational features of jaw, gyratory, cone and roll crushers. Grinding: Theory of ball mill, rod mill, critical speed of the mill, open circuit and closed circuit, circulating load. Size separation: Sieving and screening, laboratory sizing and its importance, representation and interpretation of size analysis data, industrial screening. Classification: Movement of solids in fluids, free setting and hindered settling of particles, different types of classifiers, e.g. sizing and sorting classifiers used in mineral industry.

Module II (12 Hours)
Concentration: Gravity separation, concentration criteria, jigging, flowing film concentration and tabling, dense media separation. Froth flotation: Theory, reagents used in floatation processes, machines and practice. Magnetic and electrostatic separation: Theory and application of magnetic and electrostatic separation techniques in mineral industry. Dewatering and drying: Theory and practice of thickening; filtra320tion and drying.

Module III (12 Hours)
Flow sheets: Typical flow sheets for beneficiation of iron, gold, copper, lead-zinc sulphide ores, rock phosphate, beach sand, uranium and other industrial minerals. Agglomeration techniques: Sintering, palletizing, briquetting and their applications in ferrous and non-ferrous metal industries, testing of agglomerates. Important mineral deposits in India.

Books for reference
1. Gaudin A. M., Principle of Mineral Dressing.
2. Richards R. H. and Locks C. E., Text Book of Ore Dressing.
3. Taggart A.E., Element of Ore Dressing.
4. Taggart A.E., Handbook of Mineral Dressing- Ores and Industrial Minerals.
5. Trusscott S.J., Textbook of Ore Dressing.
6. Jain S.K., Ore Dressing.
7. Willis Berry A, Mineral Processing Technology.

Material Joining & Non Destructive Testing

Module I (12 Hours)

Theory and classification of welding processes Gas, arc, resistance, pressure, submerged arc, TIG, MIG, plasma arc and electron beam welding including spot welding laser welding and diffusion welding. Mass and heat flow in fusion welding. Metallurgical effects of the weld thermal cycles.

Metallurgy of welding of structural steels, HAZ. Metallurgy of fusion welding of ferritic and austenitic steels, cast iron etc. welding pool solidification. Metallurgical principles of welding nonferrous alloys, Cu alloys, Al alloys etc., welding pool solidification, structure of welds, heat treatment and transformation.

Module II (12 Hours)

Design of welded joints, welding defects and their remedies. Inspection and testing of weldments.

Non-destructive Testing: Liquid penetrant test -Physical Principles, Procedure for penetrant testing, penetrant testing materials, Penetrant testing methods, sensitivity, Applications and limitations, typical examples. **Ultrasonic testing** - Basic properties of sound beam, Ultrasonic transducers, Inspection methods, Techniques for normal beam inspection , Techniques for angle beam inspection, Flaw characterization techniques, Applications of ultrasonic testing, Advantages and limitations.

Module III (12 Hours)

Thermography - Basic principles, Detectors and equipment, techniques, applications**. Radiography** - Basic principle**,** Electromagnetic radiation sources, radiographic imaging, Inspection techniques, applications, limitations, typical examples. **Eddy current test** - Principles, instrumentation for ECT, techniques, sensitivity, advanced eddy current test methods, applications, limitations. **Acoustic emission** - Principle of AET, Technique, instrumentation, sensitivity, applications, acoustic emission technique for leak detection.

Magnetic particle inspection - Principle of MPT, Procedure used for testing a component, sensitivity, limitations.

Books for reference:

1. Little R.L.,Welding and Welding Technology, TMH.
2. LancasterJ.F., Allen and Unwin,Metallurgy of Welding.
3. Raj B.,Kumar T.J.et.al.,Practical Non-Destructive testing.
4. Nondestructive Testing Handbook, American Society for Nondestructive Testing

ADVANCED CASTING PROCESSES

Module – I (12 hours)

Principles of casting design, pattern design considerations, pattern allowances, pattern design and construction. Features of moulding processes, equipments, mechanizations, forces acting on moulds, mould factors in metal flow, molding factors in casting design.

Module – II (12 hours)

Design of different types of cores and core prints Fundamentals of fluid flow, design of gating system, slag traps and filters etc. Types of binders and their uses in mould and core makings. Melting practices as adopted for a few metals and alloys.

Module – III (12 hours)

Concept of directional and progressive solidification, Time of solidification and Chowrinov rule, differential methods of feeder design, feeding distance, feeding efficiency, feeder aids. Feeding characteristics of alloys, types of gates and risers. gating ratio. Yield of casting and prescription for its augmentation.

Books for Reference:

1. Heine R.W., Lopper C.R. & Rosenthal P.C., Principles of Metal Casting, McGrawHill.
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.

MATERIAL FAILURE & ANALYSIS

Module-I (14 Hours)

Aims of failure analysis, Methodology of Failure Analysis, Tree analysis.Prime factors in the premature failure of metallic components and structures, Tools and techniques in failure analysis, Sources of Failures, Steps in Failure Analysis, preservation and preparation of samples for failure analysis.

Module-II (12 Hours)

Types of failures: ductile, brittle, fatigue, creep, corrosion, wear etc., fractography, mixed mode and fatigue failures, Failure mechanisms, Embrittlement phenomena, environmental effects, Failures due to faulty heat treatments, Failures in metal forming and weldments.

Module-III (12 Hours)

Case studies in failure analysis: Case histories of component failures. Typical case studies of failure of important components such as gears, shafts, pressure vessels etc. Prevention of failures.

Reference:

1. Failure Analysis & Prevention (Vol. - X), Metal Hand Book, ASM Publication.
2. Colangelo V. J. and Heiser F. A., Analysis of Metallurgical Failures, (Wiley).
3. Mobley R.K., Root cause failure analysis.
4. Dieter G.E., Mechanical Metallurgy, McGraw-Hill Company.
5. Courtney T.H., Mechanical Behaviour of Materials.
6. Rolfe S.T. and Barsom J.M., Fracture and Fatigue Control in Structures, Prentice.

Industrial Heat Treatment

Module I(12 Hours)

Heat Treatment Equipment:Furnaces, salt bath equipment, fluidized bed equipment, vacuum furnaces and auxiliary equipment, energy efficient furnace design and operation.Process and quality controlconsiderations:Temperature control, furnace atmosphere control, control of surface carbon, evaluation of C control in processed parts, furnace safety.

Module II(12 Hours)

Heat treatment of steels: TTT and CCT diagrams, conventional heat treatment processes – annealing, normalizing, hardening and tempering. Hardenability, role of alloying elements in steels. Surface hardening and chemical treatment in steels. Thermo-mechanical treatment of steels; High temperature and low temperature Thermo-Mechanical treatment.

Module III(12 Hours)

Heat treatment of Cast iron, tool steels, stainless steel and heat resistant alloys, non-ferrous alloys: Al, Cu, Mg, Ti. Annealing of precious metals.Thermo mechanical processing of steels.

Books for reference:

1.ThelningK.E., Steel and its Heat treatment, Butterworth-Heinemann.
2.Rajan and Sharma, Heat Treatment, PHI.
3. Principles of Heat Treatment of Steels, ASM

NANO MATERIALS

Module – 1 (12 hours)

Introduction: Types of nanomaterials, emergence of nanotechnology, bottom-up and top-down approaches, challenges in nanotechnology. Nanoparticles: synthesis of metallic nanoparticles, semiconductor nanoparticles, oxide nanoparticles (sol-gel processing); vapour phase reactions, solid phase segregation. Nanowires: Synthesis of nanowires by evaporation – condensation growth, VLS or SLS growth, stress induced recrystallization, template based synthesis, electrospinning, lithography. Thin Films: fundamentals of film growth, PVD, CVD and ALD.

Module – II (12 hours)

Special Nanomaterials: Carbon fullerenes and nanotubes, micro and mesoporous materials, core-shell structures, organic – inorganic hybrids, nanocomposites and nanograined materials. Nanostructures fabricated by physical techniques: lithography - photolithography, electron beam lithography, X-ray lithography, FIB lithography; nanolithography - STM, AFM, NSOM; soft lithography; assembly of nanoparticles and nanowires and other methods of microfabrication.

Module – III (12 hours)

Characterization and properties of nonmaterials: Structural characterization by XRD, SAXS, SEM, TEM, SPM, gas adsorption; Chemical characterization by spectroscopy techniques; Mechanical properties; Optical, electrical and magnetic properties. Applications of nanomaterials: molecular electronics and nanoelectronics, nanobots, biological applications, catalytic applications, quantum devices, carbon nanotube emitters, nanofluids.

Books for reference:

1. Cao G., Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press.

2. Gagotsi Y., Nanomaterails Handbook, (Ed.), Taylor and Francis.

3. Poole C. P. and Owee F. T., Introduction to Nanotechnology, Willey Press.

4. Edlstein and Cammarate, Nano Materials Synthesis, Properties and Applications.

5. Bandyopadyay A.K., Nano Materials, New age Publications.

6. Pradeep T., Nano - The Essentials, TMH.

7. Koch,C. Nanostructured Materials: Processing, Properties and applications, William Andrew Publishing.

MODELLING AND COMPUTER APPLICATION IN METALLURGY

Module I (12 Hours)

Fundamentals of Modeling, processes modeling and physical modeling. Numerical methods for solution of ordinary differential equations. Application of regression analysis and curve fitting techniques.

Module II (12 Hours)

Calculation of phase diagrams, stereographic projections. Computer applications for energy & material balance in B.F. and BOF Steel making processes.

Module III (12 Hours)

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 Modelling of Primary Metals Processing Operations, Wiley.

POWDER METALLURGY

Module I (12 Hours)

Production of powders: Mechanical, Chemical, Electrolytic and atomization Methods. Commercial production of metallic powders. Characterization of metal powders: Chemical composition and structure: Particle size and their shape, apparent and tap density, pressing properties and their determination: Powder flow, compressibility and porosity measurements:

Module II (12 Hours)

Treatment of metal powders: Behaviour of powder during compaction. Die compaction: Types of presses: Tooling and design: Modern methods of powder consolidation, Isotactic pressing: Roll compaction, Powder extrusion and forging, Slip casting, evaluation of sintered products.

Module III (12 Hours)

Sintering furnaces and atmosphere: Stages of sintering, driving forces for sintering, mechanism of sintering, liquid phase sintering, hot processing: Iron, copper and aluminium base P/M alloys: Porous materials: Friction and Antifriction materials: Brushes, Heavy alloys, Cemented carbides: Cermets, Electrical contact materials.

Books for reference:

1. German R.M., Powder Metallurgy Science
2. Lenel F.V., Powder Metallurgy
3. Hirschhorn J.S., Powder Metallurgy.
4. Goetzel C., Treatise on Powder Metallurgy – vol. 1&2.
5. Sands R.L. & Shakespeare C.R., Powder Metallurgy Practice and Applications.
6. Hausner H. H. & Mal M., Handbook of Powder Metallurgy –- 2nd Ed.

REFRACTORY

MODULE-I INTRODUCTION:
Definition: Classification of Refractories based on i). Raw materials, ii). Temperatures and iii). Shapes.
Fundamental properties of refractories: Physical, Thermal, Mechanical, Chemical and Electrical.
Testing of refractories (Indian and International Standards)

MODULE-II ACID AND BASIC REFRACTORIES:
Silica: Raw materials, Manufacturing Steps, properties and Applications.
Alumina: Raw materials, Manufacturing Steps, properties and Applications
Forsterite, Dolomite, Magnetite, Magnesia carbon and Chrome based refractories: Raw materials, Manufacturing Steps, Properties and Applications.
Phase Diagram: Al_2O_3-SiO_2 and CaO-MgO

MODULE-III SPECIAL REFRACTORIES:
Raw materials, Manufacturing steps, Properties and Applications of the following special refractories:
i). Carbide based- Silicon Carbide and Boron Carbide
ii). Nitride based- Silicon nitride
iii). Oxide based- Zirconia, Thoria, Beryllia
iv). Ceramic Fibers- Types, Properties and Applications.

MODULE-IV MONILITICS/CASTABLES:
Introduction of Monolithic Refractories/Castable Refractories, Shaped and Unshaped Refractories. Aggregate used in Monolithic/Castable Refractories. Advantages and disadvantages of Monolithic Refractories/Castable Refractories.
Classification of Castables: Conventional Castables, Low Cement Castables, Ultra Low Cement Castables, No or Zero Cement Castables, Gel bonded and Self floor Castables, Silica free and basic Castables, Manufacture of Castables/Monolithic, Area of Application of Castables/Monolithic.

Reference:

1. D.N.Nandi, Hand Book of Refractories, TATA McGraw Hill Publishing Co, New Delhi,1991
2. Refractories Manufacture Properties and Application by A.R.Chesti.
3. Refractories Manufacture Properties and Use by M.L.Mishra
4. Fuels, Furnace and refractories by J.D.Gilchrist.
5. Handbook of Monolithic, 1980, Plibrico, Japan.
6. Modern Refractories Practices, 1961, harbison Walker Comp., Pittsburgh.

TRIBOLOGY OF MATERIALS

Module I (12 Hours)

Background and importance of Tribology; A system approach to Tribology; Characterization of tribosurfaces; mechanics of solid contacts; Hertzian and non-hertzian contact. Contact pressure and deformation in non- conformal contacts, friction in contacting rough surfaces, sliding and rolling friction, various laws and theory of friction and frictional heat generation; role of contact temperature.

Module II (12 Hours)

Different modes of wear; Wear and wear types; Mechanisms of wear - Adhesive, brasive, corrosive, erosion, fatigue, fretting, etc., Wear of metals and non-metals. Wear models - asperity contact, constant and variable wear rate, geometrical influence in wear models, wear damage. Wear in various mechanical components, wear controlling techniques. Tribological testing techniques and analysis of the worn surfaces.

Module III (12 Hours)

Different wear resistant materials; recent research results illustrating the performance of surface coatings, bulk materials and composite materials in tribological contacts. Lubrication; Importance and properties of lubricants.

Books for reference:

1. K.C. Ludema, Friction, Wear, Lubrication - A Text book in Tribology, CRC press.
2. Jamal Takadoum, Materials and Surface Engineering in Tribology.
3. Hutchins, Tribology.
4. Bharat Bhusan, Principle and Application of Tribology.
5. Bharat Bhusan, Introduction to Tribology.

COMPOSITE OF MATERIALS

(WILL BE UPLOADED SOON)

BIOMATERIALS

Module I (12 Hours)

Introduction: Definition of Biomaterials: Performance of Biomaterials; Brief Historical Background. Metallic Implant Materials: Stainless Steels; Co-Based Alloys; Ti and Ti-Based Alloys; Dental Metals; Other Metals; Corrosion of Metallic Implants. Ceramic Implant Materials: Structure–Property Relationship of Ceramics; Aluminum Oxides (Alumina); Zirconium Oxides (Zirconia); Calcium Phosphate; Glass-Ceramics; Other Ceramics; Carbons; Deterioration of Ceramics.

Module II (12 Hours)

Polymeric Implant Materials: Polymerization and Properties; Effect of Structural Modification and Temperature on Properties; Polymeric Implant Materials; High-Strength Thermoplastics; Deterioration of Polymers. Composites as Biomaterials: Structure; Mechanics of Composites; . Applications of Composite Biomaterials; Biocompatibility of Composite Biomaterials. Structure–Property Relationships of Biological Materials: Proteins; Polysaccharides; Structure–Property Relationship of Tissues. Tissue Response to Implants: Normal Wound-Healing Process; Body Response to Implants; Blood Compatibility; Carcinogenicity.

Module III (12 Hours)

Soft Tissue Replacement: Sutures, Skin, and Maxillofacial Implants: Sutures, Surgical Tapes, and Adhesives; Percutaneous and Skin Implants; Maxillofacial and Other Soft-Tissue Augmentation. Blood Interfacing Implants: Blood Substitutes and Access Catheters; Cardiovascular Grafts and Stents; Blood Vessel Implants; Heart Valve Implants; Heart and Lung Assist Devices; Artificial Organs. Hard Tissue Replacement: Long Bone Repair: Wires, Pins, and Screws; Fracture Plates; Intramedullary Devices; Acceleration of Bone Healing. Joints and Teeth: Joint Replacements; Spinal Implants; Dental Restorations and Implants; Interface Problems in Orthopedic and Dental Implants.

Books for reference:

1. Park Joon and Lakes R.S., Biomaterials - An Introduction, Third Edition, Springer.

2. Ratner B.D., Hoffman A.S., Schoen F.J., Lemons J.E., Biomaterials Science: An Introduction to Materials in Medicine, Academic Press.

DEGRADATION OF MATERIALS

Module I (14 Hours)

Technological importance of corrosion study, corrosion as non equilibrium process, corrosion rate expressions, electrochemical principles of corrosion-cell analogy, concept of single electrode potential, reference electrodes, e.m.f. and galvanic series-their uses in corrosion studies, polarization, passivity. Different forms of corrosion-uniform attack, galvanic, crevice, pitting, intergranular, selective leaching, erosion, stress corrosion cracking-their characteristic features, causes and remedial measures.

Module II (12 Hours)

Principles of corrosion prevention-material selection, control of environment including inhibitors, cathodic and anodic protection, coatings and design considerations. Corrosion testing methods. Introduction to high temperature corrosion, Pilling-Bedworth ratio, oxidation kinetics, oxide defect structures, Wagner-Hauffe valence approach in alloy oxidation, catastrophic oxidation, internal oxidation.

Module III (12 Hours)

Considerations in high temperature alloy design, prevention of high temperature corrosion -use of coatings. Liquid metal attack - liquid metal embrittlement, preventive measures. Chemical degradation of non-metallic materials like rubbers, plastics, ceramics etc. Hydrogen damage - types, characteristics, mechanism and preventive measures.

Books for reference:

1. Fontana, M.G., Corrosion Engineering, McGraw-Hill.
2. Uhlig H.H., Corrosion & Corrosion control, John Wiley & Sons.
3. Evans, Introduction to Metallic Corrosion.
4. Glasstone S., Introduction to Electrochemistry.
5. Banerjee S.N., An Introduction to Science of Corrosion & its Inhibition, Oxonian Press Pvt. Ltd.

BRANCH-METALLURGICAL ENGINEERING

Specialization: **METALLURGICAL AND MATERIALS ENGINEERING**

Second Semester							
Theory					**Practical**		
Course Name	**Hours /Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Transport Phenomena in Metallurgy	4-0	4	100	50	-	-	-
Specialization Core-2 Mechanical Behavior of Materials	4-0	4	100	50	-	-	-
Elective I (Specialization related) 1.Solid State Phase Transformation 2.Mechanical Working of Materials 3.Physics of Materials 4.Process Metallurgy	4-0	4	100	50	-	-	-
Elective II(Departmental related) 1.Advanced Casting Processes 2.Material Failure and Analysis 3.Industrial Heat Treatment 4.Nano Materials 5.Modeling and Computer Application in Metallurgy 6.Powder Metallurgy 7.Refractory	4-0	4	100	50	-	-	-
Elective III (from any Department) 1.Tribology of Materials 2.Composite Materials 3.Bio Materials 4.Degradation of Materials	4-0	4	100	50	-	-	-
Lab-2 Material Processing and Process Metallurgy Lab					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

TRANSPORT PHENOMENA IN METALLURGY

Module I (12 Hours)

Momentum transfer fundamentals: properties of fluids, types of fluid flow, viscosity of liquid and gases, laminar flow, momentum balance general momentum equation(GME) and its application in flow of falling film, flow through a circular tube, flow between the parallel plates, application of Navier Stokes Equations, turbulent flow: friction factors, flow past submerged bodies, flow through packed bed of solids, fluidized beds, energy balanced application in fluid flow: conservation of energy, flow through valves and fitting, flow from ladles.

Module II (12 Hours)

Energy transport fundamentals: fouriers laws and thermal conductivity of liquids gases, solids and bulk materials, heat transfer and general energy equation and its application in heat transfer with convention and conduction in solids, examples of solidification in sand molds and metal molds, continuous casting, radiation heat transfer, black and grey body radiation, radiations from gases, its application to furnace enclosures and thermal behavior of metallurgical packed bed reactors.

Module III (12 Hours)

Mass transfer fundamentals: molar density of mixture, mole fraction, molar flux, total molar fluxes, diffusion mechanisms in solids, Fick's first law and second law of diffusion, diffusion coefficient and inter diffusion coefficient, mass fraction, mass average velocity, general mass transport equation(GMT), application of (GMT): mass transfer through a near stagnant medium, mass transfer through a near stagnant medium with chemical reaction, examples such vaporization of Zn in molten copper , Silicon growth by chemical vapour deposition, loss of liquid Mn by passes of argon gases. Convective mass transfer: forced convection and natural convection, Navier Stokes Equations, application in mass transfer in laminar film flow, mass transfer in porous solids.

Books for reference:

1. Geiger G.H. and Poirier D.R., Transport phenomena in metallurgy, addison-wesley publishing company.

2. Bird R.B.., Stewart W.E..and Lightfoot E.N., Transport phenomena. addison-wesley publishing company.

MECHANICAL BEHAVIOUR OF MATERIALS

Module-I (14 Hours)

Introduction: Theory of elasticity and plasticity, Generilised Hooke`s law, stress-strain relationship. Mechanism and crystallography of slip and twinning. Plastic response of materials-a continuum approach: classification of stress-strain curves, yield criteria.Concept of critical resolved shear stress. Deformation of single crystals and polycrystals. Hall –Petch relationship. Role of grain boundaries in deformation, strengthening mechanisms. Dislocation Theory: Elements of dislocation theory, movement of dislocation, elastic properties of dislocation, intersection of dislocation, dislocation reactions in different crystal structures, origin and multiplication of dislocations.

Module- II (14 Hours)

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. 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. 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.

Module- III (14 Hours)

Tension test- Engineering & true stress-strain curves, evaluation of tensile properties, Tensile instability, Effect of strain-rate & temperature on flow properties. Hardness tests- Brinell, Rockwell, Vickers, Meyer, Knoop, etc., relationship with flow curve. Compression Test- Comparison with tension, phenomenon of buckling &barreling. Bend Test- Pure bending & flexure formula. Impact Test- Notched bar impact tests, transition Temperature & metallurgical factors affecting it.

Books for reference:

1. Dieter G. E., Mechanical Metallurgy, McGraw-Hill.
2. Hertzberg R.W., Deformation and Fracture Mechanics of Engineering Materials John Wiley.
3. Meyers M. A. and Chawla K. K., Mechanical Behaviour of Materials.
4. Courtney T.H., Mechanical Behaviour of Materials.

SOLID STATE PHASE TRANSFORMATIONS

Module I (14 Hours)

Introduction: Thermodynamics of phase equilibrium and phase changes; Definition, utility, order and classification of phase transformations. Diffusion: Definition of Fick's law on steady and non-steady state diffusion and their solutions; Mechanism of diffusion in solids; Chemical diffusion and Darken's equation; Kirkendall effect; Effect of pressure and temperature on diffusivity. Nucleation and growth: Formation of nucleus; Homogeneous and Heterogeneous nucleation; Mechanism and kinetics of thermally activated growth; Interface and diffusion control growth regimes. Phase equilibrium and phase diagrams: Important phase changes in unary and binary systems; Types and interpretation of phase diagram; Utility of phase diagrams, Lever rule; important phase diagrams in metallic and ceramic systems; Free energy Composition diagrams; Ternary phase diagrams; Isomorphous and eutectic Systems.

Module II (12 Hours)

Solid state diffusive transformation: Classification of solid-solid transformations; Nucleation in solids; Precipitate growth; Age hardening; Spinodal decomposition; Precipitate coarsening. Order-disorder change, polymorphic change. Recrystallization, grain growth. Eutectoid transformation. Application of solid state precipitation. Pearlitic and bainitic transformations in steel; Zone refining, crystal growth, crystallography, stabilization,. Annihilation of point imperfections, ,eutectoidal reaction, cellular reaction. Strengtheming mechanisms, massive decomposition. Martensite and martensitic changes in ferrous materials.

Module III (12 Hours)

Review of Iron-carbon alloy system: Iron-cementite and iron-graphite phase diagrams, cooling of hypo- eutectoid, eutectoid and hyper-eutectoid steels, hypo-eutectic, eutectic and hyper-eutectic cast irons, nucleation and growth of pearlite. Heat treatment of steels: TTT and CCT diagrams, conventional heat treatment processes – annealing, normalizing, hardening and tempering. Hardenability, role of alloying elements in steels. Surface hardening and chemical treatment in steels. Thermo-mechanical treatment of steels; High temperature and low temperature Thermo-Mechanical treatment. Heat treatment of some Cu, Al and Ti based alloys.

Books for reference:

1. Porter D. A. and Easterling K. E., Phase Transformations in Metals and Alloys, CRC Press.
2. Sharma R. C., Phase Transformations in Materials.
3. Raghavan, Solid State Phase Transformations, PHI.
4. Thelning K E, Steel and its Heat treatment, Butterworth.
5. Rajan and Sharma, Heat Treatment, PHI.
6. Principles of Heat Treatment of Steels, ASM
7. Reed-Hill R. E., Physical Metallurgy Principles, East West Press.
8. Christian J.W., Theory of Transformations in Metals and Alloys, Pergamon Press.

MECHANICAL WORKING OF MATERIALS

Module I (14 Hours)

Classification of forming processes. Fundamentals of metal working – Flow curve for materials ,Effect of temperature, strain rate, metallurgical structure, workability and residual stress. Yielding theories, processing maps. Friction in metal working, Lubrication. Rolling - Classification & processes, load, torque, power, variables controlling process, forward slip. Fundamentals of roll pass design, mill type. Rolling practice, adopted for some common products such as slabs, blooms, billets, plates, sheets etc Rolling defects and their control. Forging - Classification & processes, load for circular & rectangular plate. Calculation of Forging load under sticking and slipping Plain strain forging analysis. Manufacture of rail wheels and tyres.

Module II (12 Hours)

Extrusion - Classification & processes, force & variables affecting it. Deformation and defects in extrusion Calculation of extrusion pressure under plain strain conditions, production of tubes and seamless pipes Drawing of Wires and Tubes- Processes, drawing stress. Calculation of drawing loads, drawing defects. Sheet metal Forming- Forming methods, Forming limit criterion, Special Forming techniques in formed products: deep drawing and redrawing. Formability diagrams, Defects in formed products.

Module III (12 Hours)

Special forming methods such as high energy forming: explosive forming, electro hydraulic and magnetic forming processes Non Destructive Testing: Scope and significance of non destructive testing. Principles, equipment, specifications and limitations of liquid penetrant, Magnetic particle, Eddy current, Ultrasonic and Acoustic emissions, and Radiography (X-Ray and Gamma Ray).

Books for reference:

1. G. E. Dieter, Mechanical Metallurgy, McGraw-Hill.
2. Roll Pass Design, The United Steel Companies Ltd., U.K.
3. C. Suryanarayana, Testing of Metallic materials.
4. C. Russak, G. W. Rowe, Principles of Industrial Metal Working Processes.
5. Baldev Raj, Practical Non Destructive Testing.

PHYSICS OF MATERIALS

Module I (12 Hours)

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.

Module II (12 Hours)

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. Optical properties, Refraction, Absorption, Absorption in dielectrics, photographic images, Luminescence, Lasers.

Module III (12 Hours)

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. Thermoelectric properties of metals and semiconductors, ionic and superionic conductivity in solids. Different types of dielectric materials, ferro, antiferro and ferri-electric materials. Piezo electric materials.

Books for References:

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.
5. Mauraka S.P. and Peckrar M.C., Electronic Materials Science and Technology, Academic Press.
6. Rose-innes A.C. and Rhoderick E.H., Introduction to Superconductivity, Pergamon press, Oxford.
7. Srivastava C.M. and Srinivasan C., Science of Engineering Materials, New Age Pub., New Delhi.
8. Kittel C., Introduction to Solid State Physics, John Wiley.
9. Streetman B.G., Solid State Electronic Devices, Prentice Hall, New Delhi.
10. Goldman A., Van Nostrand, Modern Ferrite Technology, New York.

PROCESS METALLURGY

Module I (12 Hours)

Introduction: Scope of extractive Metallurgy, Occurrence of Metals in Nature, Minerals diagrams for oxides and sulphides. Introduction to mineral beneficiation, sampling, liberation studies and its importance. Unit operation of Comminution, Grinding, Size separation, Classification, Concentration, Froth flotation, Magnetic and electrostatic separation, Dewatering and drying

Module II (12 Hours)

Pyrometallurgy: Ore preparation, Calcination, Roasting, Predominance area diagram, Roasting and Ores, Elementary concepts of extraction of Metals from their ores. Ellingham 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.

Module III (12 Hours)

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. Flow sheets: Typical flow sheets for beneficiation of iron, gold, copper, lead-zinc sulphide ores, rock phosphate, beach sand, uranium and other industrial minerals. Problems related to the process metallurgy

Books for references:

1. Newton J., Extractive Metallurgy, Wiley.
2. Gilchrist J.D., Extraction Metallurgy, Pergamon.
3. Rosenqvist T., Principles of Extractive Metallurgy, McGraw Hill.
4. Ghosh Ahindra, Chatterjee A., Ironmaking and Steelmaking Theory and Practices, PHI Pvt. Ltd.

ADVANCED CASTING PROCESSES

Module – I (12 hours)

Principles of casting design, pattern design considerations, pattern allowances, pattern design and construction. Features of moulding processes, equipments, mechanizations, forces acting on moulds, mould factors in metal flow, molding factors in casting design.

Module – II (12 hours)

Design of different types of cores and core prints Fundamentals of fluid flow, design of gating system, slag traps and filters etc. Types of binders and their uses in mould and core makings. Melting practices as adopted for a few metals and alloys.

Module – III (12 hours)

Concept of directional and progressive solidification, Time of solidification and Chowrinov rule, differential methods of feeder design, feeding distance, feeding efficiency, feeder aids. Feeding characteristics of alloys, types of gates and risers. gating ratio. Yield of casting and prescription for its augmentation.

Books for Reference:

1. Heine R.W., Lopper C.R. & Rosenthal P.C., Principles of Metal Casting, McGrawHill.
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.

MATERIAL FAILURE & ANALYSIS

Module-I (14 Hours)

Aims of failure analysis, Methodology of Failure Analysis, Tree analysis.Prime factors in the premature failure of metallic components and structures, Tools and techniques in failure analysis, Sources of Failures, Steps in Failure Analysis, preservation and preparation of samples for failure analysis.

Module-II (12 Hours)

Types of failures: ductile, brittle, fatigue, creep, corrosion, wear etc., fractography, mixed mode and fatigue failures, Failure mechanisms, Embrittlement phenomena, environmental effects, Failures due to faulty heat treatments, Failures in metal forming and weldments.

Module-III (12 Hours)

Case studies in failure analysis: Case histories of component failures. Typical case studies of failure of important components such as gears, shafts, pressure vessels etc. Prevention of failures.

Reference:

1. Failure Analysis & Prevention (Vol. - X), Metal Hand Book, ASM Publication.
2. Colangelo V. J. and Heiser F. A., Analysis of Metallurgical Failures, (Wiley).
3. Mobley R.K., Root cause failure analysis.
4. Dieter G.E., Mechanical Metallurgy, McGraw-Hill Company.
5. Courtney T.H., Mechanical Behaviour of Materials.
6. Rolfe S.T. and Barsom J.M., Fracture and Fatigue Control in Structures, Prentice.

Industrial Heat Treatment

Module I(12 Hours)

Heat Treatment Equipment:Furnaces, salt bath equipment, fluidized bed equipment, vacuum furnaces and auxiliary equipment, energy efficient furnace design and operation.Process and quality controlconsiderations:Temperature control, furnace atmosphere control, control of surface carbon, evaluation of C control in processed parts, furnace safety.

Module II(12 Hours)

Heat treatment of steels: TTT and CCT diagrams, conventional heat treatment processes – annealing, normalizing, hardening and tempering. Hardenability, role of alloying elements in steels. Surface hardening and chemical treatment in steels. Thermo-mechanical treatment of steels; High temperature and low temperature Thermo-Mechanical treatment.

Module III(12 Hours)

Heat treatment of Cast iron, tool steels, stainless steel and heat resistant alloys, non-ferrous alloys: Al, Cu, Mg, Ti. Annealing of precious metals.Thermo mechanical processing of steels.

Books for reference:

1.ThelningK.E., Steel and its Heat treatment, Butterworth-Heinemann.
2.Rajan and Sharma, Heat Treatment, PHI.
3. Principles of Heat Treatment of Steels, ASM

NANO MATERIALS

Module – 1 (12 hours)

Introduction: Types of nanomaterials, emergence of nanotechnology, bottom-up and top-down approaches, challenges in nanotechnology. Nanoparticles: synthesis of metallic nanoparticles, semiconductor nanoparticles, oxide nanoparticles (sol-gel processing); vapour phase reactions, solid phase segregation. Nanowires: Synthesis of nanowires by evaporation – condensation growth, VLS or SLS growth, stress induced recrystallization, template based synthesis, electrospinning, lithography. Thin Films: fundamentals of film growth, PVD, CVD and ALD.

Module – II (12 hours)

Special Nanomaterials: Carbon fullerenes and nanotubes, micro and mesoporous materials, core-shell structures, organic – inorganic hybrids, nanocomposites and nanograined materials. Nanostructures fabricated by physical techniques: lithography - photolithography, electron beam lithography, X-ray lithography, FIB lithography; nanolithography - STM, AFM, NSOM; soft lithography; assembly of nanoparticles and nanowires and other methods of microfabrication.

Module – III (12 hours)

Characterization and properties of nonmaterials: Structural characterization by XRD, SAXS, SEM, TEM, SPM, gas adsorption; Chemical characterization by spectroscopy techniques; Mechanical properties; Optical, electrical and magnetic properties. Applications of nanomaterials: molecular electronics and nanoelectronics, nanobots, biological applications, catalytic applications, quantum devices, carbon nanotube emitters, nanofluids.

Books for reference:

1. Cao G., Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press.

2. Gagotsi Y., Nanomaterails Handbook, (Ed.), Taylor and Francis.

3. Poole C. P. and Owee F. T., Introduction to Nanotechnology, Willey Press.

4. Edlstein and Cammarate, Nano Materials Synthesis, Properties and Applications.

5. Bandyopadyay A.K., Nano Materials, New age Publications.

6. Pradeep T., Nano - The Essentials, TMH.

7. Koch,C. Nanostructured Materials: Processing, Properties and applications, William Andrew Publishing.

MODELLING AND COMPUTER APPLICATION IN METALLURGY

Module I (12 Hours)

Fundamentals of Modeling, processes modeling and physical modeling. Numerical methods for solution of ordinary differential equations. Application of regression analysis and curve fitting techniques.

Module II (12 Hours)

Calculation of phase diagrams, stereographic projections. Computer applications for energy & material balance in B.F. and BOF Steel making processes.

Module III (12 Hours)

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 Modelling of Primary Metals Processing Operations, Wiley.

POWDER METALLURGY

Module I (12 Hours)

Production of powders: Mechanical, Chemical, Electrolytic and atomization Methods. Commercial production of metallic powders. Characterization of metal powders: Chemical composition and structure: Particle size and their shape, apparent and tap density, pressing properties and their determination: Powder flow, compressibility and porosity measurements:

Module II (12 Hours)

Treatment of metal powders: Behaviour of powder during compaction. Die compaction: Types of presses: Tooling and design: Modern methods of powder consolidation, Isotactic pressing: Roll compaction, Powder extrusion and forging, Slip casting, evaluation of sintered products.

Module III (12 Hours)

Sintering furnaces and atmosphere: Stages of sintering, driving forces for sintering, mechanism of sintering, liquid phase sintering, hot processing: Iron, copper and aluminium base P/M alloys: Porous materials: Friction and Antifriction materials: Brushes, Heavy alloys, Cemented carbides: Cermets, Electrical contact materials.

Books for reference:

1. German R.M., Powder Metallurgy Science
2. Lenel F.V., Powder Metallurgy
3. Hirschhorn J.S., Powder Metallurgy.
4. Goetzel C., Treatise on Powder Metallurgy – vol. 1&2.
5. Sands R.L. & Shakespeare C.R., Powder Metallurgy Practice and Applications.
6. Hausner H. H. & Mal M., Handbook of Powder Metallurgy –- 2nd Ed.

REFRACTORY

MODULE-I INTRODUCTION:
Definition: Classification of Refractories based on i). Raw materials, ii). Temperatures and iii). Shapes.
Fundamental properties of refractories: Physical, Thermal, Mechanical, Chemical and Electrical.
Testing of refractories (Indian and International Standards)

MODULE-II ACID AND BASIC REFRACTORIES:
Silica: Raw materials, Manufacturing Steps, properties and Applications.
Alumina: Raw materials, Manufacturing Steps, properties and Applications
Forsterite, Dolomite, Magnetite, Magnesia carbon and Chrome based refractories: Raw materials, Manufacturing Steps, Properties and Applications.
Phase Diagram: Al_2O_3-SiO_2 and CaO-MgO

MODULE-III SPECIAL REFRACTORIES:
Raw materials, Manufacturing steps, Properties and Applications of the following special refractories:
i). Carbide based- Silicon Carbide and Boron Carbide
ii). Nitride based- Silicon nitride
iii). Oxide based- Zirconia, Thoria, Beryllia
iv). Ceramic Fibers- Types, Properties and Applications.

MODULE-IV MONILITICS/CASTABLES:
Introduction of Monolithic Refractories/Castable Refractories, Shaped and Unshaped Refractories. Aggregate used in Monolithic/Castable Refractories. Advantages and disadvantages of Monolithic Refractories/Castable Refractories.
Classification of Castables: Conventional Castables, Low Cement Castables, Ultra Low Cement Castables, No or Zero Cement Castables, Gel bonded and Self floor Castables, Silica free and basic Castables, Manufacture of Castables/Monolithic, Area of Application of Castables/Monolithic.

Reference:

1. D.N.Nandi, Hand Book of Refractories, TATA McGraw Hill Publishing Co, New Delhi,1991
2. Refractories Manufacture Properties and Application by A.R.Chesti.
3. Refractories Manufacture Properties and Use by M.L.Mishra
4. Fuels, Furnace and refractories by J.D.Gilchrist.
5. Handbook of Monolithic, 1980, Plibrico, Japan.
6. Modern Refractories Practices, 1961, harbison Walker Comp., Pittsburgh.

TRIBOLOGY OF MATERIALS

Module I (12 Hours)

Background and importance of Tribology; A system approach to Tribology; Characterization of tribosurfaces; mechanics of solid contacts; Hertzian and non-hertzian contact. Contact pressure and deformation in non- conformal contacts, friction in contacting rough surfaces, sliding and rolling friction, various laws and theory of friction and frictional heat generation; role of contact temperature.

Module II (12 Hours)

Different modes of wear; Wear and wear types; Mechanisms of wear - Adhesive, brasive, corrosive, erosion, fatigue, fretting, etc., Wear of metals and non-metals. Wear models - asperity contact, constant and variable wear rate, geometrical influence in wear models, wear damage. Wear in various mechanical components, wear controlling techniques. Tribological testing techniques and analysis of the worn surfaces.

Module III (12 Hours)

Different wear resistant materials; recent research results illustrating the performance of surface coatings, bulk materials and composite materials in tribological contacts. Lubrication; Importance and properties of lubricants.

Books for reference:

1. K.C. Ludema, Friction, Wear, Lubrication - A Text book in Tribology, CRC press.
2. Jamal Takadoum, Materials and Surface Engineering in Tribology.
3. Hutchins, Tribology.
4. Bharat Bhusan, Principle and Application of Tribology.
5. Bharat Bhusan, Introduction to Tribology.

COMPOSITE OF MATERIALS

(WILL BE UPLOADED SOON)

BIOMATERIALS

Module I (12 Hours)

Introduction: Definition of Biomaterials: Performance of Biomaterials; Brief Historical Background. Metallic Implant Materials: Stainless Steels; Co-Based Alloys; Ti and Ti-Based Alloys; Dental Metals; Other Metals; Corrosion of Metallic Implants. Ceramic Implant Materials: Structure–Property Relationship of Ceramics; Aluminum Oxides (Alumina); Zirconium Oxides (Zirconia); Calcium Phosphate; Glass-Ceramics; Other Ceramics; Carbons; Deterioration of Ceramics.

Module II (12 Hours)

Polymeric Implant Materials: Polymerization and Properties; Effect of Structural Modification and Temperature on Properties; Polymeric Implant Materials; High-Strength Thermoplastics; Deterioration of Polymers. Composites as Biomaterials: Structure; Mechanics of Composites; . Applications of Composite Biomaterials; Biocompatibility of Composite Biomaterials. Structure–Property Relationships of Biological Materials: Proteins; Polysaccharides; Structure–Property Relationship of Tissues. Tissue Response to Implants: Normal Wound-Healing Process; Body Response to Implants; Blood Compatibility; Carcinogenicity.

Module III (12 Hours)

Soft Tissue Replacement: Sutures, Skin, and Maxillofacial Implants: Sutures, Surgical Tapes, and Adhesives; Percutaneous and Skin Implants; Maxillofacial and Other Soft-Tissue Augmentation. Blood Interfacing Implants: Blood Substitutes and Access Catheters; Cardiovascular Grafts and Stents; Blood Vessel Implants; Heart Valve Implants; Heart and Lung Assist Devices; Artificial Organs. Hard Tissue Replacement: Long Bone Repair: Wires, Pins, and Screws; Fracture Plates; Intramedullary Devices; Acceleration of Bone Healing. Joints and Teeth: Joint Replacements; Spinal Implants; Dental Restorations and Implants; Interface Problems in Orthopedic and Dental Implants.

Books for reference:

1. Park Joon and Lakes R.S., Biomaterials - An Introduction, Third Edition, Springer.

2. Ratner B.D., Hoffman A.S., Schoen F.J., Lemons J.E., Biomaterials Science: An Introduction to Materials in Medicine, Academic Press.

DEGRADATION OF MATERIALS

Module I (14 Hours)

Technological importance of corrosion study, corrosion as non equilibrium process, corrosion rate expressions, electrochemical principles of corrosion-cell analogy, concept of single electrode potential, reference electrodes, e.m.f. and galvanic series-their uses in corrosion studies, polarization, passivity. Different forms of corrosion-uniform attack, galvanic, crevice, pitting, intergranular, selective leaching, erosion, stress corrosion cracking-their characteristic features, causes and remedial measures.

Module II (12 Hours)

Principles of corrosion prevention-material selection, control of environment including inhibitors, cathodic and anodic protection, coatings and design considerations. Corrosion testing methods. Introduction to high temperature corrosion, Pilling-Bedworth ratio, oxidation kinetics, oxide defect structures, Wagner-Hauffe valence approach in alloy oxidation, catastrophic oxidation, internal oxidation.

Module III (12 Hours)

Considerations in high temperature alloy design, prevention of high temperature corrosion -use of coatings. Liquid metal attack - liquid metal embrittlement, preventive measures. Chemical degradation of non-metallic materials like rubbers, plastics, ceramics etc. Hydrogen damage - types, characteristics, mechanism and preventive measures.

Books for reference:

1. Fontana, M.G., Corrosion Engineering, McGraw-Hill.
2. Uhlig H.H., Corrosion & Corrosion control, John Wiley & Sons.
3. Evans, Introduction to Metallic Corrosion.
4. Glasstone S., Introduction to Electrochemistry.
5. Banerjee S.N., An Introduction to Science of Corrosion & its Inhibition, Oxonian Press Pvt. Ltd.