Department of Metallurgical and Material Engineering

Curriculum of M.Tech (Metallurgical and Material Engineering)

FIRST SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	MM 601	Metallurgical Thermodynamics & Kinetics	3-1-3	4
2	MM 611	Phase Transformation of Materials	3-1-0	4
3		Professional Elective – I	3-1-0	4
4		Professional Elective – II	3-1-0	4
5		Professional Elective – III	3-1-0	4
6	MM 671	Metallurgical Thermodynamics & Kinetics Lab.	0-0-3	2
7	MM 673	Phase Transformation Laboratory	0-0-3	2
8	MM 685	Seminar & Technical Writing – I	3-1-0	2
TOTAL				**26**

SECOND SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	MM 642	Advances in Materials Science & Engineering	3-1-0	4
2	MM 652	Experimental Techniques in Materials Engineering	3-1-0	4
3		Professional Elective – IV	3-1-0	4
4		Professional Elective – V	3-1-0	4
5		Professional Elective – VI	3-1-0	4
6	MM 672	Experimental Techniques in Materials Engineering Lab.	0-0-3	2
7	MM 674	Material Science Lab.	0-0-3	2
8	MM 686	Seminar & Technical Writing – II	0-0-3	2
TOTAL				**26**

THIRD SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1.	MM 687	Seminar & Technical Writing – III		2
2.	MM 691	Summer Research / Industrial Project		4
3.	MM 693	Research Project Work – I		8
4.	MM 695	Research Project Review – I		8
TOTAL				**22**

FOURTH SEMESTER

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1.	MM 688	Seminar & Technical Writing – IV		2
2.	MM 692	Comprehensive Viva - Voce		4
3.	MM 694	Research Project Work – II		8
4.	MM 696	Research Project Review – II		6
5.	MM 699	Dissertation		8
TOTAL				**24**

LIST OF PROFESSIONAL ELECTIVES

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1.	MM 606	X – Ray & Electron Microscopy	3-1-0	4
2.	MM 615	Structure & Properties of Materials (not available to MM graduates)	3-1-0	4
3.	MM 616	Alloy Steel Technology	3-1-0	4
4.	MM 617	Physical Metallurgy of Advanced Metallic Materials	3-1-0	4
5.	MM 618	Joining of Materials	3-0-0	3
6.	MM 619	Physical Metallurgy of Alloy Steels	3-1-0	4
7.	MM 623	Iron & Steel Making (not available to MM graduates)	3-1-0	4
8.	MM 624	Advanced Foundry Technology	3-0-0	3
9.	MM 625	Ferro – Alloy Technology	3-0-0	3
10.	MM 628	Advances in Steel Making	3-1-0	4
11.	MM 635	Fracture Mechanics & Failure Analysis	3-1-0	4
12.	MM 636	Advanced Processing of Materials	3-0-0	3
13.	MM 637	Mechanical Behaviour of Materials	3-1-0	4
14.	MM 638	Mechanical Working of Materials	3-1-0	4
15.	MM 646	Composite Materials	3-1-0	4
16.	MM 655	Transport Phenomena	3-0-0	3
17.	MM 656	Corrosion and Degradation of Materials and their Prevention	3-0-0	3
18.	MM 657	Environmental Pollution in Metallurgical Industries	3-0-0	3
19.	MM 681	Special Topics in Metallurgical and Material Engineering – I		03/04
20.	MM 682	Special Topics in Metallurgical and Material Engineering – I		03/04
21.	MM 683	Special Laboratory in Metallurgical and Material Engineering – I	0-0-3	2
22.	MM 684	Special Laboratory in Metallurgical and Material Engineering – I	0-0-3	2

LIST OF PROFESSIONAL ELECTIVES OFFERED BY OTHER DEPARTMENT

Sl. No.	Sub. Code	Subject	L-T-P	Credits
1	CR 603	Energetic	3-1-0	4
2	CR 613	Refractories for Metallurgical & Allied Processes	3-1-0	4
3	CR 625	Advanced Structural Ceramics	3-1-0	4
4	CR 638	Ceramics in High Tech. Applications	3-1-0	4
5	CS 612	Software Engineering	3-1-0	4
6	CS 630	Artificial Intelligence	3-1-0	4

SUMMARY OF COURSES

Sub Discipline: Physical Metallurgy

MM 606	X – Ray & Electron Microscopy	3-1-0	4
MM 611	Phase Transformation of Materials	3-1-0	4
MM 615	Structure & Properties of Materials (not available to MM graduates)	3-1-0	4
MM 616	Alloy Steel Technology	3-1-0	4
MM 617	Physical Metallurgy of Advanced Metallic Materials	3-1-0	4
MM 619	Physical Metallurgy of Alloy Steels	3-1-0	4
MM 618	Joining of Materials	3-1-0	4

Sub Discipline: Process Metallurgy

MM 601	Metallurgical Thermodynamics & Kinetics	3-1-0	4
MM 623	Iron & Steel Making	3-1-0	4
MM 624	Advanced Foundry Technology	3-0-0	3
MM 625	Ferro – Alloy Technology	3-0-0	3
MM 628	Advances in Steel Making	3-1-0	4

Sub Discipline: Mechanical Metallurgy

MM 635	Fracture Mechanics & Failure Analysis	3-1-0	4
MM 636	Advanced Processing of Materials	3-0-0	3
MM 637	Mechanical Behaviour of Materials	3-1-0	4
MM 638	Mechanical Working of Materials	3-1-0	4

Sub Discipline: Advanced Materials

MM 642	Advances in Materials Science and Engineering	3-1-0	4
MM 646	Composite Materials	3-1-0	4

Sub Discipline: Allied Courses

MM 652	Experimental Techniques in Materials Engineering	3-1-0	6
MM 655	Transport Phenomena	3-0-0	3
MM 656	Corrosion and Degradation of Materials and their Prevention	3-0-0	3
MM 657	Environmental Pollution in Metallurgical Industries	3-0-0	3

Sub Discipline: Laboratory Courses

MM 671	Metallurgical Thermodynamics & Kinetics Lab.	0-0-3	2
MM 672	Experimental Techniques in Materials Engineering Lab.	0-0-3	2
MM 673	Phase Transformation Laboratory	0-0-3	2
MM 674	Material Science Lab.	0-0-3	2

Sub Discipline: Project, Seminar and Special Courses

MM 681	Special Topics in Metallurgical and Material Engineering – I		03/04
MM 682	Special Topics in Metallurgical and Material Engineering – I		03/04
MM 683	Special Laboratory in Metallurgical and Material Engineering – I	0-0-3	2
MM 684	Special Laboratory in Metallurgical and Material Engineering – I	0-0-3	2
MM 685	Seminar & Technical Writing – I	3-1-0	4
MM 686	Seminar & Technical Writing – II	0-0-3	2
MM 687	Seminar & Technical Writing – III		2
MM 688	Seminar & Technical Writing – IV		2
MM 691	Summer Research / Industrial Project		4
MM 692	Comprehensive Viva – Voce		4
MM 693	Research Project Work – I		8
MM 694	Research Project Work – II		8
MM 695	Research Project Review – I		8
MM 696	Research Project Review – II		6
MM 699	Dissertation		8

DETAILED SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
MM 601	Metallurgical Thermodynamics & Kinetics	3-1-0	4
MM 606	X – Ray & Electron Microscopy	3-1-0	4
MM 611	Phase Transformation of Materials	3-1-0	4
MM 615	Structure & Properties of Materials (not available to MM graduates)	3-1-0	4
MM 616	Alloy Steel Technology	3-1-0	4
MM 617	Physical Metallurgy of Advanced Metallic Materials	3-1-0	4
MM 618	Joining of Materials	3-0-0	3
MM 619	Physical Metallurgy of Alloy Steels	3-1-0	4
MM 623	Iron & Steel Making	3-1-0	4
MM 624	Advanced Foundry Technology	3-0-0	3
MM 625	Ferro – Alloy Technology	3-0-0	3
MM 628	Advances in Steel Making	3-1-0	4
MM 635	Fracture Mechanics & Failure Analysis	3-1-0	4
MM 636	Advanced Processing of Materials	3-0-0	3
MM 637	Mechanical Behaviour of Materials	3-1-0	4
MM 638	Mechanical Working of Materials	3-1-0	4
MM 642	Advances in Materials Science and Engineering	3-1-0	4
MM 646	Composite Materials	3-1-0	4
MM 652	Experimental Techniques in Materials Engineering	3-1-0	6
MM 655	Transport Phenomena	3-0-0	3
MM 656	Corrosion and Degradation of Materials and their Prevention	3-0-0	3
MM 657	Environmental Pollution in Metallurgical Industries	3-0-0	3
MM 671	Metallurgical Thermodynamics & Kinetics Lab.	0-0-3	2
MM 672	Experimental Techniques in Materials Engineering Lab.	0-0-3	2
MM 673	Phase Transformation Laboratory	0-0-3	2
MM 674	Material Science Lab.	0-0-3	2
MM 681	Special Topics in Metallurgical and Material Engineering – I		03/04
MM 682	Special Topics in Metallurgical and Material Engineering – I		03/04
MM 683	Special Laboratory in Metallurgical and Material Engineering – I	0-0-3	2
MM 684	Special Laboratory in Metallurgical and Material Engineering – I	0-0-3	2
MM 685	Seminar & Technical Writing – I	3-1-0	4
MM 686	Seminar & Technical Writing – II	0-0-3	2
MM 687	Seminar & Technical Writing – III		2
MM 688	Seminar & Technical Writing – IV		2
MM 691	Summer Research / Industrial Project		4
MM 692	Comprehensive Viva – Voce		4

MM 693	Research Project Work – I		8
MM 694	Research Project Work – II		8
MM 695	Research Project Review – I		8
MM 696	Research Project Review – II		6
MM 699	Dissertation		8

DETAILED SYLLABI OF COURSES

MM 601 METALLURGICAL THERMODYNAMICS & KINETICS 4 Credits [3-1-0]

Laws of thermodynamics and their applications; Enthalpy; Entropy associated with different processes; Gibbs and Helmholtz free energy; Criteria of equilibrium; Concepts of activity, fugacity and standard states; Ellingham diagram; Free energy – composition diagram; Solutions – Raoult's and Henry's Laws; Ideal, real and regular solutions; Gibbs – Duhem equation. ; Activation energy and its applications; Homogeneous and heterogeneous reactions; Factors affecting the heterogeneous reactions kinetics in solid – solid, solid – gas and solid – liquid systems; Rate controlling steps; Kinetic model equations, Fick's laws of diffusions and their applications in metallurgy; Slag – metal reaction kinetics ; Concept of boundary layer and its impact on reaction kinetics.

Caretaker: Prof.M.Kumar

Essential Readings:

1. D.R.Gaskell, *Introduction to Metallurgical Thermodynamics*, McGraw Hill, New York, 1973.
2. G.S.Upadhyay and R.K.Dubey, *Problems in Metallurgical Thermodynamics and Kinetics*, Pergamon, New York, 1977.
3. J.Szekely and N.J.Themelis, *Rate Phenomena in Process Metallurgy*, John Wiley, New York.

Supplementary Readings:

1. A.K.Mohanty, *Rate Processes in Extractive Metallurgy*, Prentice Hall of India.

MM 606 X-RAY & ELECTRON MICROSCOPY 4 credits [3-1-0]

X-ray and electron beam analysis techniques: Characterization of x-rays, absorption, x-ray diffraction techniques (viz. Laue, powder and rotating crystal methods), interpretation of diffraction datas, qualitative and quantitative phase composition analysis, analysis of particle size, residual stress/strain, phase diagram determination, order disorder transformation study. ; X-ray fluorescence: Origin, basic theory/concept, characterization of materials through x-ray fluorescence. ; Microscopy with light and electrons: Introduction, Methods of image formation, Pixels, the light-optical microscope, Magnification, Resolution, depth of field and depth of focus, Aberrations in optical system, electron versus light. ; Electrons and their interaction with specimen: Introduction, Electrons, generation of electrons-magnetic lenses, the scattering of electrons by atoms, Elastic scattering, Inelastic scattering, secondary effect, the family of electron microscopes. ; The transmission electron microscope: The instrument, Contrast mechanisms, Bright field & Dark field imaging, SAD technique. ; The scanning electron microscope: How it works, obtaining a signal in the SEM, the optics of the SEM, the

performance of the SEM, the ultimate resolution of the SEM, Topographic images, compositional images, Crystallographic informations from the SEM, the use of generated signals in SEM study. ; Chemical analysis in the electron microscope: The generation of x-rays from/on the specimen, Quantitative analysis in an electron microscope, Electron energy loss spectroscopy (EELS).

Caretaker: Prof.S.C.Mishra

Essential Reading:

1. B.D.Cullity, *Element of X-ray Diffraction*, Addison Wesley.
2. C.S.Barret and T.B. Massalski, *Structure of Metals*, McGraw Hill.
3. V.A. Phillip, *Modern Metallographic Technique & their Application*, Wiley Interscience Publ., 1971.

Supplementary Reading:

1. S.K.Chaterjee, *X-ray Diffraction, its theory and applications*, PHI.
2. P.J. Goodhow, J.Humhreys, R.Beanland: *Electron microscopy & Analysis (III Edn.)*; Taylor & Francis (publ.) 2001.

MM 611 PHASE TRANSFORMATION OF MATERIALS 4 credits [3-1-0]

Thermodynamics and Kinetics of solid state Phase transformation, Atomic models of Diffusion, Functions of alloying elements, Allotropy of Iron and Fe – C Phase diagram, Importance of Austenite Grain size. ; Formation of Austenite, TTT and CCT Diagrams. ; Homogeneous and Heterogeneous nucleations, Strain energy effects. ; Pearlitic, Bainiatic and Martensitic Transformation (Mechanisms, Kinetics and Morphologies). ; Pearlitic transformation: Factors influencing pearlitic transformation, Mechanism of transformation, Nucleation of growth, Orientation relationship. ; Bainite transformation: Mechanism of transformation, Nucleation and growth, Orientation relationship, Surface relief, Classical and non-classical morphology, Effect of alloying elements. ; Martensitic Transformation: Characteristics of transformation, Thermodynamics and kinetics, Nucleation and growth, Morphology, Crystallography, Stabilization. ; Annealing (Full, Homogenising, Spherodization and Stress-relieving annealing), Normalising, Comparison of Annealing and Normalizing, Hardening and Tempering of steel, Aims and stages of tempering, Effect of Carbon and alloying elements, Tempering of alloy steels and Multiply tempering.

Caretaker: Prof. B.C.Ray

Essential Reading:

1. D.A.Porter & K E Easterling, *Phase Transformation in Metals and Alloys*, CRC Press.
2. V Raghvan, *Solid State Phase Transformation*, PHI.
3. V Sing, *Heat Treatment of Metals*, Standard Publishers.

Supplementary Reading:

1. J W Christian, *The Theory of Transformations in Metals and Alloys*, Pergamon Press.
2. J E Hilliard, *Phase Transformations*, ASM.
3. S.H. Avner, *Introduction to Physical Metallurgy*, Tata McGraw – Hill.
4. R.E. Reed Hill, *Physical Metallurgy Principles*, East – West Press.
5. A K Jena and M C Chaturvedi, *Phase Transformation in Materials*, Prentice Hall.

MM 615 STRUCTURE AND PROPERTIES OF MATERIALS 4 credits [3-1-0]

Crystal Structure: Space lattices, Bravais lattices and Reciprocal lattice concept. Miller Indices of planes and directions. ; Bonding in Solids: Ionic, Covalent, and Metallic bonding. Theory of alloy formation, Solid solution, Substitutional and interstitial solid solution, Hume Rothery Rules, Intermetallic compounds, Normal valency compounds, Electron compounds, Interstitial compounds. ; Imperfections: Point defects: vacancies, Interstitialcies, Dislocations: Edge & Screw dislocations, Burgers vector. ; Binary Phase Diagrams: Isomorphous, Eutectic, Peritectic, Eutectoid, Monotectic & Syntectic systems. Phase rule and Lever rule. ; Iron-Cementite Equilibrium diagrams and its applications. ; Diffusion: Fick's First and Second law of diffusion. Atomic model of diffusion. Grain boundary, surface and thermal diffusion. Kirkendall Effect, Grube method, Matano method, Interstitial diffusion. ; Nucleation: Homogeneous and Heterogeneous nucleation, Kinetics of nucleation. Growth and overall transformation kinetics.

Caretaker: Prof. D. Chaira

Essential Reading:

1. V. Raghavan, *Materials Science and Engineering*, Prentice-Hall of India Private Limited (2003).
2. W.F. Smith, *Principles of Materials Science and Engineering*, McGraw Hill, New York (1994).

Supplementary Reading:

1. R.E. Reid Hill, *Physical Metallurgy Principles*- PWS-Kent Publishing (2004).
2. V. Singh, *Physical Metallurgy*, Standard Publisher (2008).
3. W.D.Callister, *An Introduction Materials Science & Engineering*, John Wiley & Sons (2007).
4. L.H. Van Vlack, *Elements of Materials Science and Engineering*, Addison Wisley, New York (1985).

MM 616 ALLOY STEEL TECHNOLOGY 4 credits [3-1-0]

Production Technology ; Electric arc furnace: Design, Construction and operation, Refractory lining, Electrode movement and slag control, Manufacture of alloy steels such as low alloy steels, stainless steels, Tool steels and silicon steels. ; Induction melting furnace: Classification, Construction and Refractory lining, Operation and manufacture of alloy steels. ; Processing, microstructure & mechanical properties of different alloy steels such as HSLA steels, Dual phase steels, IF steels, stainless steels, silicon steels, high speed steels, ball bearing steels, Had field steels etc.

Caretaker: Prof.S.Sarkar

Essential Reading:

1. F.P. Edneral: *Electrometallurgy of Steel and Ferro – Alloys*, Vol. I, Mir Publishers, 1979.
2. R.W.K.Honeycomb: *Steels, Microstructures and Properties*, Edward Arnold.

Supplementary Reading:

1. G.Karuss, *Steel Heat Treatments and Processing Principles,* ASM.
2. P.G.Shewmon, *Transformations in Metals*, McGraw Hill.
3. Dr. S. Smith, *Principles of Materials Science and Engineering*, McGraw Hill.

4. J.D. Verhoeven, *Fundamentals of Physical Metallurgy*, John Wiley.

MM 617 PHYSICAL METALLURGY OF ADVANCED METALLIC MATERIALS **4 credits [3-1-0]**

Special steel: High strength low alloy (HSLA) steel, Dual phase steel, Duplex stainless steel, TRIP steel, Maraging steel, High speed steel, Stainless steel: ferritic, austenitic and martensitic. Precipitation & dispersion hardenable materials, Age hardenable alloys: Al-Cu alloys, Al-Fe-V-Si alloys. Super alloys: Ni, Fe and Co based super alloys, Ti based alloys & their thermomechanical treatment, Nanomaterials: Synthesis, properties and applications. ; Non-structural materials: Dielectric materials; dielectric constant and polarization, linear dielectric materials, capacitors and insulators, non-linear dielectrics, pyro, piezo and ferro-electrics properties; Semiconductor: direct and indirect band gap, band diagrams, applications of semiconductors, degenerate and non-degenerate semiconductors, extrinsic and intrinsic semiconductors. Superconducting materials, Optical & Photoionic materials, electron-hole-recombination. Biomaterials, property requirements for biomaterials, concept of biocompatibility, important biometallic alloys; Ti based, stainless steel. Intelligent materials.

Caretaker: Prof. D.Chaira.

Essential Reading:

1. W.F. Smith, *Principles of Materials Science and Engineering,* Mc Graw Hill, New York (1994).
2. W.D. Callister, *An Introduction Materials Science & Engineering*, John Wiley & Sons (2007).

Supplementary Reading:

1. V. Raghavan, *Material Science and Engineering*, Prentice Hall of India, 2004.
2. R.Sharma, Sharma, *Heat Treatment: principles and techniques*, Prentice Hall of India, (2004).

MM 618 JOINING OF MATERIALS **3 credits [3-0-0]**

Introduction: Principle, Theory and Classification of welding and other joining processes. ; Manual metal arc (MMA): Equipment requirement, electrodes for welding of structural steels, coating constituents and their functions, types of coatings, current and voltage selection for electrodes, Arc welding power sources; Conventional welding transformers, rectifiers and current and voltage. The influence of these power sources on welding. Metal transfer. ; Submerged arc welding (SAW): Process details, consumables such as fluxes and wires for welding mild steel, Variations in submerged arc welding process. ; Gas metal arc welding (GMAW) or MIG/ MAG welding: Process details, shielding gases, electrode wires, their sizes, and welding current ranges. TIG welding: Process details, power sources requirements, electrode sizes and materials, current carrying capacities of different electrodes, shielding gases, application of process. Resistance welding: General principle of heat generation in resistance welding, application of resistance welding processes. ; Process details and working principle of spot, seam, and. projection welding, electrode materials, shapes of electrodes, electrode cooling, selection of welding currents, voltages. ; Welding metallurgy of carbon and alloy steels, Cast irons, Stainless steels, Al- and Cu-based alloys. Weldability and Heat affected zones (HAZ). ; Welding defects and detection techniques. ; Soldering and brazing: Difference between both the processes, consumables used, methods of brazing, fluxes used, their purposes and flux residue treatment.

Caretaker: Prof. B C Ray

Essential Reading:

1. J F Lancaster, *Metallurgy of Welding*, Allen and Unwin.
2. R L Little, *Welding and Welding Technology*, TMH.

Supplementary Reading:

1. J. Norrish, *Advanced Welding Processes*, Woodhead.
2. K Weman, *Welding Processes Handbook*, Woodhead.

MM 619 PHYSICAL METALLURGY OF ALLOY STEELS 4 credits [3-1-0]

Effect of alloying elements on steels. Hot rolling of structural steels. High Strength Low Alloy (HSLA) steels; Controlled rolling of HSLA steels. Strengthening mechanisms in HSLA steels: Grain size control and precipitation strengthening Ausforming, Isoforming; Dual phase steels: Metallurgy and Thermo mechanical processing. ; Stainless steels: Austenitic, Ferritic, Martensitic Stainless Steels. Schaeffler diagram. Effect of martensitic and other phases in Austenitic Stainless Steels. Sensitization of Austenitic Stainless Steels. Intermetallic phases and 475^0C embrittlement in Ferritic Stainless Steels. Martensitic Stainless Steel, their heat treatment Precipitation Hardening Stainless Steels. ; Duplex stainless steels. ; High speed steels: Their composition and heat treatment. ; Hadfied steels: their composition, heat treatment. Ball bearing steels. ; Marging steels: Their composition, heat treatment.

Caretaker: Prof.A.K.Panda

Essential Reading:

1. R.W.K. Honeycombe and H K D H Bhadesia, *Steels Microstructure & Properties – (2nd Edition)* Edward Arnold, 1995, ISBN No. 0-340-58946-9.
2. I Tamura, H.Sekine, T Tanaka, and C.Ouchi, *Thermo Mechanical Processing of High Strength Low Alloy Steels*, Butterworths (1988), ISBN No. 0-408-11034-1.
3. G Kranss, *Steels Heat Treatment and Processing Principles,* ASM International, Materials Park, Ohio 44073, ISBN No. 0-87170-370-X.

Supplementary Reading:

1. *HSLA steels Metallurgy and Applications (Conference Proceedings),* ASM International (1986), ISBN No. 0-87170-299-0.
2. C.R. Brooks, *Principles of the Heat Treatment of Plain Carbon and Low Alloy Steels,* ASM International, (1996), ISBN No. 0-87170-538-9.

MM 623 IRON AND STEEL MAKING 4 Credits [3-1-0]

Blast Furnace Route for Iron Making: The blast furnace and its accessories; The burden and its preparation; Physical and Chemical processes in a blast furnace, Blast furnace slag and its control; Control of hot metal composition; Blast furnace plant and accessories; Modern trends in blast furnace practice; Control of irregularities in the blast furnace. ; Alternative Methods: Need for alternative methods, Sponge iron production by using solid and gaseous reductants, Smelting reduction processes. ; Modern Steel Making: Different routes of steel making. Oxygen steel making; Top and bottom blown converter processes, Hybrid processes. Electric steel making; Electric arc furnaces, Induction furnaces, Secondary steel making. ; Casting of Liquid

Steel: Ingot casting of steel, Continuous casting of steel, Iron and steel scenario in India in the last decade.

Caretaker: Prof. S.Sarkar

Essential Reading:

1. A.Ghosh and A.Chatterjee, *Iron Making & Steel Making Theory and Practice* –Prentice – Hall of India Pvt. Ltd., 2008.

Supplementary Reading:

1. A.K Biswas, *Principles of Blast Furnace Iron Making* –SBA Publication, 1999.
2. D.H Wakelin, *The Making, Shaping and Treating of Steel (Iron making volume)*, The AISE Steel Foundation, 2004.
3. R.J. Fruehan (Ed.), *The Making, Shaping and Treating of Steel (Steel making volume)* –, The AISE Steel Foundation, 2004.

MM 624 ADVANCED FOUNDRY TECHNOLOGY 3 credits [3-0-0]

Critical review of some foundry operations: Various casting processes, Mould reinforcements, Mould factors in Metal flow, Moulding factors in casting design, Limitations in controlling some moulding factors in casting design, Effect of process variables on property of core and Mould making sand. ; Properties of Liquid Metals: Thermal properties, Viscosity, Surface tension and Density of Liquid metals and their role in Foundry Technology. ; Gases in Liquid Metals: Simple gases in Metals, Complex gases in Metals, Gas-defects and their control. ; Solidification of Metals and Alloys: Plane front solidification, Interface stability, Dendritic growth, Cellular growth, Independent nucleation, Structure of casting as influenced by alloy constituents, Thermal conditions, Inherent nucleation and growth condition in the liquid like Temperature gradient, Liquidus temperature profile and G/R ratio. Brief discussion on control of cast structure. ; Principles of Gating and Risering, The concept of yield: Directionality in solidification, Freezing characteristics of different alloys, Measures for obtaining a solid-casting through directionality in solidification, Chworinov rule, Design of gating system, Wlodawer system of determining the feeder head requirements. Feeder head efficiency, concept of feeding range, Use of supplementary techniques and introduction of design modifications for increasing feeder-head efficiency. ; Special Casting Processes: Investment casting, Die casting, Centrifugal Casting, Full-mould casting, Vaccum-shield casting, etc. ; Industrial Melting Practices: Aim of Melting and post melting treatment. A brief idea about various melting units and their working. Industrial Melting practice as adopted in case of a few Metals and alloys like C.I. Steel, Cu, Al, etc. ; Casting Defects and their Remedies: Shaping faults arising in pouring, Inclusions and sand defects, Gas defects. Shrinkage defects during solidification in liquid phase. Contraction defects after solidification, Dimensional errors, Compositional errors and segregation.

Caretaker: Prof. U.K. Mohanty

Essential Reading:

1. P.R. Beeley, *Foundry Technology*, 2001 edition, Publisher – Butterworth & Co.

Supplementary Reading:

1. P.C. Mukherjee, *Fundamentals of Metal Castiang Technology.*
2. P.D. Webster, *Fundamentals of Foundry Technology.*

MM 625 FERRO-ALLOY TECHNOLOGY 3 credits [3-0-0]

General survey of ferroalloy industries in India and its future prospect, use of ferroalloys in Iron & Steel Industries. ; Ferro-alloy furnaces – principle of submerged electric arc furnace, design of submerged electric arc furnace, transformer capacity, electrode manufacture; thermodynamics and kinetics of ferro alloy production; production of ferro silicon, ferro chrome, ferro manganese, calcium silicon alloy, ferro titanium, ferro boron, ferro vanadium, ferro-niobium, ferro tungsten etc., raw materials; process conditions etc; safety aspects in the production and storage of ferroalloys, techno-economic indices; use of ferroalloys. Numeral problems based on the above.

Caretaker: Prof. S. Sarkar

Essential Reading:

1. F.B. Edneral, *Electrometallurgy of Steel and Ferro-Alloys* –Vol.2, Mir Publisher.

Supplementary Reading:

1. Riss & Khodorusky, *Production of Ferro-Alloys* –Mir Publisher

MM 628 ADVANCES IN STEEL MAKING 4 credits [3-1-0]

A critical appraisal of hybrid blowing process, Ultra high power electric arc furnace and induction furnace with respect to raw materials, energy consumption, productivity and product quality; special grade steels. ; Development of secondary steel making and their importance under Indian conditions, sources of inclusions, sulphur, phosphorus and gases in steel; secondary steel making technologies; inert gas purging, vacuum degassing – RH/DH, OD, VAD etc., ladle furnace; powder injection system – powder dispenser, lance etc.; physicochemical and fluid dynamic aspects of powder injection and stirring processes; role of slag and powders in inclusion control, desulphurization; cored wired feeding; production of ultra low Sulphur, ultra low phosphorus and inclusion free steels, ultra-low carbon steels; modification of inclusion morphologies. ; Production of stainless steel through VOD, AOD, CLU processes. Production of Ultraclean steel through post solidification treatments (VAR, ESR processes). ; Refractory for secondary steel technology-slide gate, porous plug, ladle lining etc., properties and selection of refractories.

Caretaker: Prof.S.Sarkar

Essential Reading:

1. A. Ghosh, *Secondary Steel Making – Principle & Applications*, CRC Press, 2001.
2. A. Ghosh & A. Chatterjee: *Iron Making & Steel Making Theory and Practice*, Prentice – Hall of India Pvt. Ltd., 2008

Supplementary Reading:

1. F.P. Edneral: *Electrometallurgy of Steel and Ferro – Alloys*, Vol. 1, Mir Publishers, 1979.
2. A. Ghosh, *Principles of Secondary Processing & Casting of Liquid Steel*, Oxford & IBH Publication.

MM 635 FRACTURE MECHANICS AND FAILURE ANALYSIS **4 credits [3-1-0]**

Stress intensity factor, Stress analysis of cracks, Strain energy release rate, Derivation of relationship between strain energy release rate and stress intensity factor, Crack-tip plastic zone, Dugdale's plastic strip model. ; Fracture mode transition: Plane stress versus plane strain, Crack opening displacement, Plane strain fracture toughness (K_{IC}) testing, Fracture toughness determination with elastic plastic analysis (J_{IC}), Concept of R-curve and fracture toughness measurement using it, Microstructural aspect of fracture toughness, Optimizing microstructure and alloy cleanliness to enhance fracture toughness. ; Fatigue stress life approach, Basquin's equation, Fatigue strain life approach, Low cycle fatigue, Cofin-Manson's equation, Fatigue total strain life relation, Fatigue life calculation using this approach, Neuber's analysis for notched specimens. ; Fatigue crack growth rate, Paris law, Fatigue life calculation using this approach, Mechanism of fatigue crack nucleation and propagation, Factors affecting fatigue crack growth rate, Influence of load interaction, Short fatigue crack. ; Stress corrosion cracking and K_{ISCC} determination, Corrosion fatigue, Temper embrittlement, Hydrogen embrittlement, Liquid metal embrittlement, Neutron embrit-tlement. ; Fractographic analysis of ductile, brittle, fatigue and high temperature fractured surfaces. ; Failure Analysis: Steps involved in it. Case studies of some engineering failures.

Caretaker: Prof. A. K. Panda

Essential Reading:

1. R.W. Hertzberg, *Deformation and Fracture Mechanics of Engineering Materials* - (John Wiley & Sons Pub.).
2. *Metal Hand Book, Failure Analysis & Prevention (Vol. - X)* - ASM Publication

Supplementary Reading:

1. G.E. Dieter, *Mechanical Metallurgy* by Mc-Graw Hill (1988).
2. D. Broek, *Elementary Fracture Mechanics* - Martinus Nijho Publisher.
3. N. Perez, *Fracture Mechanics,* Klwer Academic Publishers.

MM 636 ADVANCED PROCESSING OF MATERIALS **3 credits [3-0-0]**

Rapid solidification, Powder processing, Preparation and consolidation of nanopowders, Sintering, Spark Plasma and Microwave sintering, Shock compaction, Severe plastic deformation, Mechanical Alloying, near-net-shape forming, self-sustaining high temperature synthesis, sol-gel processing, zone refining, molecular beam epitaxy, laser processing, EDM, etching, CMP (Chemical Mechanical Polishing)technology Freeze casting, glass-ceramic seals, optical/photonic media, hybrid materials, solution-derived materials, solid oxide fuel cells, armor ceramics, Processing and manufacturing technologies for non-oxide and oxide based structural ceramics, composites, multifunctional materials. ; Stereolithography (SLA), selective laser sintering (SLS), direct metal laser sintering; (DMLS) and laser engineered net shaping (LENS), Spray formed tooling for rapid manufacture, Plasma spray coating. ; Preparation of single crystals, doping, sputter coating, CVD and EVD process, Inkjet printing as a manufacturing tool. ; Modelling, commercial softwares such as FLUENT and Comsol Multiphysics.

Caretaker: Mr. S.N. Alam

Essential Reading:

1. W.F. Smith, *Principles of Material Science and Engineering*, McGraw Hill, 1990.
2. O. Tatsuki, *Advanced processing & manufacturing technologies for structural & multifunctional materials*, Lavoisier, 2007.
3. O.Tatsuki, M.Singh, J.Salem, D. Zhu*, Advanced Processing and Manufacturing Technologies for Structural and Multifunctional Materials, (eds.)*, Ceramic Engineering and Science Proceedings. Vol. 28(7).1st Edition 2007. ISBN-10: 0-470-19638-6 - John Wiley & Sons.

Supplementary Reading:

1. R.Hugon, *Thin Film Technology*, Elsevier Pub., UK, 1978.
2. L.Pawlowski, *The Science and Engineering of Thermal Spray Coatings*, John Wiley Publications, New York, 1995.
3. F. Kongoli (Editor), R.G. Reddy (Editor) *Advanced Processing of Metals and Materials: New, Improved and Existing Technologies: Iron and Steel; Recycling and Waste Treatment* Vol.5, Publisher: The Minerals, Metals & Materials Society ISBN-10: 0873396383.
4. G.Goodman, M. Dekkar, *Ceramic Materials for Electronics*, New York, 1968.
5. S.Kalpakjian, S. Schmid, *Manufacturing Engineering and Technology*, Prentice Hall; 5th edition, ISBN-10: 0131489658, 2005.

MM 637 MECHANICAL BEHAVIOUR OF METALS 4 credits [3-1-0]

Dislocation Theory: Introduction, dislocation reaction, cross slip and climb of dislocations, Dislocation sources and dislocation multiplication, Dislocation pile ups. ; Tensile Behaviours of Metals: True stress-true strain curve, Strain hardening coefficient, Instability in tension, Effect of strain rate and temperature on flow properties. ; Fracture: Griffith's theory of brittle fracture, Mechanism of brittle and ductile fracture, Fractographic aspects of fracture, Notch effects. ; Impact Behaviour: Notch bar impact test, Transition temperature phenomenon, Instrumented Chapry test. ; Fracture Mechanics: Strain energy release rate, Stress intensity factor, Plan strain facture toughness, Crack-tip plastic zone, Dugdale's plastic strip model, Fracture toughness determination with elastic plastic analysis (J_{IC}), Design approach. ; Fatigue: Micromechanisms of crack initiation and growth, Stress and strain approaches of fatigue, Fracture mechanics approach, Fatigue crack growth, Life prediction. ; Creep: Creep curves, Mechanisms of creep, Stress rapture test, Life prediction, High temperature alloys. ; Environmental Assisted Cracking: Stress corrosion cracking, Hydrogen embrittlement, Corrosion fatigue.

Caretaker: Dr. B. B. Verma.

Essential Reading:

1. G E Dieter, *Mechanical Metallurgy* –McGraw – Hill Publication (1988).
2. R W Hertzberg, *Deformation and Fracture Mechanics of Engineering Materials* – John Wiley & Sons Publication (1995).

Supplementary Reading:

1. R E Reed, *Physical Metallurgy Principals,* Hill Litton Education Publication (2004).
2. W.Soboyejo, *Mechanical Properties of Engineering Materials,* Marcel Dekker Publication (2003).

MM 638 MECHANICAL WORKING OF MATERIALS 4 credits [3-1-0]

Fundamentals of Metal working processes: Theory of plasticity and yield – criterion, Workability Tests, Hot working, Cold working and warm (semi-hot) working of metals, structure of cold worked and hot worked metals. ; Rolling of Metals: Various rolling Mills and rolling processes, Theories of Hot and Cold rolling Defects in rolling and their remedial measures. Rolling Mill Control, Concepts of roll-pass-design, Roll pass design of some simple shapes like Flat products, Blooms, rounds, etc. ; Forging of Metals: Type of forging processes, Die design, Various forging equipments, Forging defects and their remedies, Load and energy requirements in Forging, Forging of Rail wheels and tyres. ; Extrusion of Metals: Types of Extrusion processes, Metal flow in Extrusion process, Variables in extrusion, Extrusion defects and their remedies, Load and energy requirements, sheathing and cladding by Extrusion. ; Drawing of Metals: Type of operation, Dies, Load and Energy requirement, Drawing of seamless Tubes. ; Sheet Metal Forming: Operations, Equipment, Technology, Defects and their remedies. ; Non conventional Processes: High Energy rate forming processes Explosive forming of Metals, Electromagnetic forming.

Caretaker: Prof. U.K.Mohanty

Essential Reading:

1. G.E. Dieter, *Mechanical Metallurgy*.
2. A.Ghosh & A. Mallick. *Manufacturing Sciences*.

Supplementary Reading:

1. P.Polukhin, N.Fedosov, A.Korolyov & Y. Matveyer, *Rolling Mill Practice,* Making Shaping and Treating of Steel.

MM 642 ADVANCES IN MATERIALS SCIENCE AND ENGINEERING 4 credits [3-1-0]

Introduction: Various classes of advanced materials. ; Ultra light Materials and Metallic Foams: Material Definition and Processing, Characterization of cellular metals, Material properties and applications. ; Bio-Materials: Various types of biomaterials, Biopolymer, Bioceramics, Nanostructured bio-materials, Classes of materials used in medicine, Application of materials in medicine and dentistry, Various materials and coatings for implants. ; Composite Materials: Material definition and classifications, Advanced polymer composite, Ceramic composite, Metal matrix composite, Nanocomposite, Applications. ; Coatings, surface modification and high temperature materials. ; Semiconductors: Electronic structure, Macroscopic properties, Applications. ; Smart materials: Piezoelectric materials, Shape memory alloys, Magnetic shape memory, Thin film shape memory alloys for MEMS application; Super alloys: Types of super alloys, Properties and applications. ; Structural Ceramics: Crystalline and amorphous ceramics, Bonding in ceramics, Properties, Applications.

Caretaker: Mr. S. Mula

Essential Reading:

1. Jr. W. D. Callister, *Materials Science and Engineering*, An Introduction, 5th Edition, John Wiley & Sons, Inc., New York, 1999, with CD-ROM.
2. R E Smallman, A.H.W. Ngan, *Physical Metallurgy and Advanced Materials, Seventh Edition*, Butterworth-Heinemann, 2007, ISBN: 0750669063.

3. Edited by B.D. Ratner, A.S. Hoffman, F.J. Sckoen, and J.E.L Emons, *Biomaterials Science, An Introduction to Materials in Medicine*, Academic Press, Second edition, 2004.

Supplementary Reading:

1. Edited by H.P. Degischer & B. Kriszt, *Handbook of Cellular metals, Production, processing, Application,* Wiley - VCH, 2002.
2. Edited by J. R. Davis, *Handbook of Materials for Medical Devices,* ASM international, 2003.
3. L.J. Gibson, and M.F. Ashby, *Cellular Solids, Structure and Properties*, 2nd Edition, Cambridge University Press, 1999.
4. Ashby, M. F. Evans, A. Fleck, N. A. Gibson, L. J. Hutchinson, J. W. & Wadley, *H. N. G. Metal Foams: A Design Guide*, Butterworth-Heinmann, Massachusetts; 2000.
5. Disegi, Kennedy, and Pilliar, *Cobalt-Base Alloys for Biomedical Applications,* ASTM-STP1365.
6. J.F. Shackelford, *Advanced Ceramics, Vol.1- Bioceramics,* Gordon and Breach Science Publishers, 1999.
7. M. Ohring, *Materials Science of Thin Films*, 2nd Edition, Academic Press, 2002.
8. C.T. Herakovich, *Mechanics of Fibrous Composites*, John Wiley & Sons, Inc., New York, 1998.
9. M.P. Grover, *Fundamentals of Modern Manufacturing*, Materials, *Processing, and Systems*, 2nd edition, John Wiley & Sons, Inc.
10. S.Suresh, A. Mortensen and A. Needleman, *Fundamentals of metal matrix composites*, Butterworth Heinemann, 1993.
11. Henkel and Pense, *Structure and properties of engineering materials, fifth edition*, McGraw Hill, 2002.

MM 646 COMPOSITE MATERIALS 4 credits [3-1-0]

Introduction to Composites, Matrices, Reinforcements, Classifications, Applications, Advantages, Fundamental concept of reinforcement, review of current developments; design fabrication and economic considerations. ; Basic mechanics of reinforcement, Stiffness of parallel arrays of fibres in a matrix. Discontinuous and particulate reinforcement. Fibres and resin materials. Rule of Mixtures, Critical Fiber Length, Short and Continuous Fibers, Fiber Orientation. ; Matrix and Reinforcement Materials, Polymeric Matrices, Metallic Matrices, Ceramic Matrices, Particulates, Flakes, Whiskers, Fibers: C, B, Glass, Aramid, Al_2O_3, SiC, Nature and manufacture of glass, carbon and aramid fibres. Review of the principal thermosetting and thermoplastic polymer matrix systems for composites. ; Polymer Matrix Composites (PMCs), Metal Matrix Composites (MMCs), Ceramic Matrix Composites (CMCs), CFRP & Carbon/Carbon Composites (CCCs) ; Types, Manufacturing, Processing methods, Interfaces, Properties, Applications, Toughening Mechanisms, Fiber Forms, Prepregs, Molding Compounds-Processes, Lay-Ups, Filament Winding, Pultrusion, Recycling. ; Matrix – Reinforcement Interface, Wettability, Interactions at Interface, Interfacial Bonding Types, Interfacial Strength Tests, The role of the interface. The nature of fiber surfaces, wetting and adhesion. ; Strength, Stiffness, Fracture, Toughness and toughening mechanisms of composites ; Strengths of unidirectional composites. Multiple fracture in Laminates. Macroscopic fracture and energy dissipating processes. Application of fracture mechanics to composite materials. Fracture Mechanics and Fracture Toughness in Composites, Linear Elastic fracture mechanics, Toughness, Fiber matrix debonding, Fiber Pullout Buckling and Post-Buckling ; Failure criteria,

Fatigue and Creep in composites, Environmental effects in Composites, Green composites. ; Synthesis and Properties of Nanocomposites. ; Green Composites.

Caretaker: Prof. B.C. Ray

Essential Reading:

1. Chawla, *Composite Materials: Science and Engineering*, Springer, 2nd Ed. 1998.

Supplementary Reading:

1. Matthews & Rawlings, *Composite Materials: Engineering and Science,* Chapman & Hall, 1994.
2. Hull, *An Introduction+ to Composite Materials,* Cambridge, 2nd Edt. 1997.

MM 652 EXPERIMENTAL TECHNIQUES IN MATERIALS ENGINEERING 4 credits [3-1-0]

X-ray and diffraction: Characterization of x-rays, absorption, x-ray diffraction techniques, interpretation of diffraction datas, qualitative and quantitative phase analysis, analysis of particle size, residual stress/strain, phase diagram determination, order disorder transformation study. ; X-ray fluorescence: Origin, basic theory/concept, characterization of materials through x-ray fluorescence. ; Electron microscopy: TEM & SEM, construction, different components & their functions, aberration of electron lenses, depth of field & depth of focus etc. Bright field & dark field image, SAD image etc., microprobe analysis. ; WDS & EDS: Principle, application for analytical studies. ; Spectroscopic analysis techniques: Fundamental principles of spectroscopy, origin of molecular & atomic spectra, atomic absorption & molecular absorption. ; Fundamentals of Flame emission & atomic absorption spectrometry: Flame emission spectroscopy & Flame spectra, chemical reaction in flames, effect of organic solvants on flame spectra, instrumentation, Photosensitive detectors, different methods of sample analysis, errors in flame photometry. ; Absorption spectroscopy: Infrared spectroscopy, FTIR (Fourier transform infrared spectroscopy) nuclear magnetic resonance (NMR) spectral analysis. ; Atomic emission spectroscopy: Emission sources, atomic emission spectrometers. ; Thermal analysis techniques: Thermo gravimetric analysis, differential thermal analysis and differential scanning calorimetry, the basis, instrumentation, data acquisition and interpretation of analytical results.

Caretaker: Prof.S.C.Mishra

Essential Reading:

1. B.D.Culity, *Elements of X – Ray Diffraction,* Addison-Wesley Publication.
2. P.J.Goodhow, J.Humbreys & R.Beanland, *Electron Microscopy & Analysis (III Edn.);* Taylor & Francis Publ., 2001.
3. D. Brandon & W.D. Kaplan, *Microstructural Characterization of Materials;* John Wiley & Sons Publ., 1999.

Supplementary Reading:

1. O.Kubashewski, E. Vans & C.B. Alcock: *Metallurgical Thermochemistry*, Pergamon Press, 1967.
2. G.Thomas: *Trasmission Electron Microscopy*.
3. A.Guthrie & R.K.Wakerling: *Vaccum Equipments and Techniques*; McGraw Hill, New York.
4. B.Chalmers & A.G.Quarell: *Physical Examinations of Metals*, Edward Arnold, 1960.
5. E.C. Subba Rao; *Metal Experiments in Material Science*, T.M.H. 1973.

MM 655 TRANSPORT PHENOMENA 3 credits [3-0-0]

Fluid flow: Review of basic principles, Continuity and Navier stokes equation, Some special solution of Navier stokes equation, Boundary layer equations and some solutions, Significance of stream functions, Stability of laminar flow and the causes of transition to turbulence, Bubble in liquids, Behaviour of droplets, Friction factor, Pressure drop in flow, Energy requirements for flow of fluids, Jets and jet behaviour, Compressible fluid flow, Fluid flow in packed and fluidized beds. ; Heat Transfer : Review of basic principles, Heat conduction equation and its solution for some simple boundary conditions, Heating and cooling of bodies , Heat transfer by convection, Energy equation, Correlation for heat transfer coefficient, Concept of thermal boundary layer in natural and forced connective Heat Transfer by radiation, Review of basic laws, View factor, Radiant heat exchange between surfaces, Radiation from gasses and flames, Heat transfer with change of phases, Combined effects of conduction, convection and radiation in Metallurgical systems, Heat transfer in packed beds and fluidized beds. ; Basic concepts of mass transfer: Diffusion and mechanism of diffusion in solids, Ficks Law, Diffusion in multi component system, Connective mass transfer, Mass transfer coefficient, Mass transfer in laminar and turbulent flow, Correlations for mass transfer coefficient combined effect to heat, Mass and momentum transfer, Application to metallurgical processes.

Caretaker: Mrs. A. Mallik

Essential Readings:

1. R.B. Bird, W.E. Stewart & E.N. Lightfoot: *Transport Phenomena*, John Wiley & Sons Inc., New York 1994.
2. G.H. Geoger & D.R. Poirer: *Transport Phenomena in Metallurgical*, Addison-Wesely Publishing Co., Reading, Mass, U.S.A. 1973.
3. A.K. Mohanty: *Rate Processes in Metallurgy,* Prentice – Hall, New Delhi, India-2000.

Supplementary Reading:

1. *Journal of Heat Transfer*, Trans, ASME.
2. C.V.Seshadri & S.V. Patankar; *Journal of Iron and Steel Institute*. Elements of Fluid Mechanics, Prentice – Hall (India) Ltd., New Delhi, 1971.

MM 656 CORROSION AND DEGRADATION OF MATERIALS AND THEIR PREVENTION 3 credits [3-0-0]

Degradation of materials: Oxidation, corrosion and wear. Basics of thermodynamics and kinetics of oxidation and corrosion. Pourbaix diagram, Polarization, Mixed potential theory. Passivity, Characteristics of passivation, Degredation of composites. ; Corrosion: Fundamentals of corrosion studies. Different types of corrosion. Atmospheric, galvanic, pitting, crevice corrosion, intergranular and de-alloying. Stress corrosion cracking, season cracking, Hydrogen damage and radiation damage. Hydrogen embrittlement. Corrosion rate measurement. Weld-decay and knife line attack. Taffel's extrapolation. Oxidation and hot corrosion of materials at high temperature. Kinetics of oxidation. Pilling-Bed worth ratio. ; Prevention of degradation: Alloying environment, environmental conditioning, design modification, cathodic and anodic protection, organic and inorganic coating, inhibitors and passivators. Wear resistant coating.

Caretaker: Mr. D.Chaira

Essential Reading:

1. M.G. Fontana& N.D Greens, *Corrosion Engineering*- Mc Graw Hill publishing company, (2006).
2. H.H. Uhlig, *Corrosion & Corrosion Control*, John Wiley & Sons, (2000).

Supplementary Reading:

1. S.N. Banerjee, *An introduction to science of corrosion & its inhibition*, Oxonian Press Pvt. Ltd., India, (1985).

MM 657 ENVIRONMENTAL POLLUTION IN METALLURGICAL INDUSTRIES **3 credits [3-0-0]**

Various types of solid, liquid and gaseous pollutants and their harmful effects; Environmental impact assessment in metallurgical industries; Pollutant emissions from integrated iron and steel plants, sponge iron plants, etc.; Environmental aspects of coal and metal mines; Management of solid, liquid and gas wastes generated during iron and steel making operations; Pollutant emissions from Al, Zn and Pb industries; Preventive measures to reduce atmospheric pollution from these industries. ; Scope of alternative energy sources to combat pollution from metallurgical industries; Environmental legislation related to metallurgical industries.

Caretaker: Prof. M. Kumar

Essential Reading:

1. C.S.Rao, *Environmental pollution controls engineering*, Willey Eastern Ltd., 1991.
2. R.C. Gupta, *Proceedings of the International Conference on Environmental Management in Metallurgical Industries*, EMMI – 2000, 14 – 16th December, 2000, Editor – Allied Publisher Ltd., Kolkata.

Supplementary Readings:

1. G.N.Pandey and G.C.Carney, *Environmental Engineering,* Tata McGraw Hill Publishing Co., 1989.

Notes:

No description of syllabi for the following codes:

MM 671	Metallurgical Thermodynamics & Kinetics Lab.	0-0-3	2
MM 672	Experimental Techniques in Materials Engineering Lab.	0-0-3	2
MM 673	Phase Transformation Laboratory	0-0-3	2
MM 674	Material Science Lab.	0-0-3	2