Department of Mechanical Engineering

Curriculum for M. Tech. Programme in Materials Science and Technology

Semester 1

Code	Title of Course	L	T	P/S	C
ME6501	Mechanical Behaviour of Materials	3	--	--	3
ME6502	Ferrous and Non-Ferrous Metallurgy	3	--	--	3
MA6001	Mathematical methods	3	--	--	3
PH6001	Physics of Materials	3	--	--	3
	Elective I	3	--	--	3
	Elective-II	3	--	--	3
ME6591	Materials Science Lab I	--	--	3	1
ME6592	Seminar I	--	--	3	1
	Total	**20**			

Semester 2

Code	Title of Course	L	T	P/S	C
ME6511	Composite Materials: Mechanics, Manufacturing and Design	3	--	--	3
ME6512	Ceramic Science and Technology	3	--	--	3
ME6513	Metal Casting and Joining	3	--	--	3
CY6001	Polymer Science and Engineering	3	--	--	3
	Elective III	3	--	--	3
	Elective IV	3	--	--	3
ME6593	Materials Science Lab II	--	--	3	1
ME6594	Term Paper/Mini Project/Industrial Training	--	--	3	1
	Total	**20**			

Semester 3

Code	Title of Course	L	T	P/S	C
ME7595	Project work	--	--	--	8
	Total	**8**			

Semester 4

Code	Title of Course	L	T	P/S	C
ME7596	Project work	--	--	--	12
	Total	**12**			

Total Credits: 60

Stipulations:

1. A minimum of 60 credits have to be earned for the award of M. Tech. degree in this programme.
2. Students have to credit a minimum of eight core courses and four electives during the programme; however they have option to credit two electives in the Third Semester, drawing one each from First and Second Semesters.
3. Students may undergo Industrial Training during May-June.

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List of Electives

Sl. No.	Code	Title of Course	Credit
1	ME6521	Thermodynamics of Materials	3
2	ME6522	Powder and Sintered parts	3
3	ME6523	Nuclear Metallurgy	3
4	ME6524	Science of solidification process	3
5	ME6525	Characterisation of Materials	3
6	ME6526	Corrosion Science and Technology	3
7	ME6527	Heat treatment Technology	3
8	ME6212	Advanced Computational Methods in Fluid Flow and Heat Transfer	3
9	ME6302	Metal Forming	3
10	ME6303	Metrology & Computer Aided Inspection	3
11	ME6312	Quality Engineering & Management	3
12	ME6322	Computer Graphics	3
13	ME6323	Six Sigma	3
14	ME6325	Finite Element Methods and Applications	3
15	ME6329	Design of Experiments	3
16	ME6330	Industrial Tribology	3

Note: Students may choose course offered in the Institute with the approval from the Programme Coordinator

DEPARTMENT OF MECHANICAL ENGINEERING

BRIEF SYLLABI

M. Tech. Programme in Materials Science and Technology

Pre-requisite for courses: Nil
Total Hours for all courses except for Project: 42
Lecture hours for theory courses: 3
Hours for Practical/Seminar: 3
Credit for theory courses: 3
Credit for Practical/Seminar: 1

MA6001 MATHEMATICAL METHODS

Vector Spaces, Inner Product Spaces, Linear Transformations, Change of Bases, Power Series Solution about Ordinary Point and Singular Points, Sturm-Liouville Problem and Generalized Fourier Series, First Order Partial Differential Equations, Second Order Partial Differential Equations, Classification, Formilation and Method of Solutions of Wave Equation, Heat equation and Laplace equation, Spaces of N-dimensions, Coordinate transformations, covariant, contravariant and mixed tensors, Fundamental Operation with tensors, Quotient Law, Christoffel's symbols, Covariant derivative.

ME6502 MECHANICAL BEHAVIOR OF MATERIALS

Elements of dislocation theory, deformation processes other than slip, deformation behaviour of solids emphasizing relations between alloy-chemistry, microstructure and properties - theories of solid solution strengthening, theories of precipitation strengthening, theories of polycrystalline strengthening, theories of deformation in coarse multiphase systems, study of the relation between stress, strain, strain rate and temperature for plastically deformable bodies, deformation mechanism maps, creep and super plasticity in solids, deformation behaviour of irradiated materials, computer modelling of microstructure-deformation behaviour relations in solids.

ME6503 FERROUS AND NON-FERROUS METALLURGY

Classification of cast alloys - cast irons, cast steels, cast nonferrous alloys; cast irons: solidification of Fe-C-Si alloys, with special reference to eutectic solidification, effect of cooling rate and composition on cast structure; classification of cast irons, - grey, malleable, nodular, compacted and chilled irons. Alloy cast irons specifications, metallurgical characteristics and founding principles of different types of cast irons, austempered ductile irons and applications. Cast steels: melting, casting, structure control and heat treatment of cast steels with special reference to Hadfield Mn steel, austenitic stainless steel and low alloy steels, physical metallurgy principles involved in alloy design and heat treatment, a critical study of founding problems involved. Cast nonferrous alloys: alloy design, melting, degassing and casting of Al-base, Mg-base, Cu-base and Ni-base casting alloys, a critical analysis of the foundry problems encountered in the production of cast nonferrous alloys. Testing of cast alloys: design of test pieces, destructive and non-destructive testing methods.

ME6591 MATERIALS SCIENCE LAB I

Specimen preparation and microstructure studies using Metallurgical and Scanning electron Microscope, Testing of metals –hardness, fatigue, Surface roughness measurement, study of Coordinate measuring machine, Metrology, NDT testing such as ultrasonic, die-penetrant and magnetic particle techniques, Testing of weldments. Use of software in materials engineering- Solid modeling exercises on advanced Softwares like 'I-DEAS' 'Pro-Engineer', 'CATIA', Exercises on finite element analysis using ANSYS and ABAQUS software.

ME6550 COMPOSITE MATERIALS: MECHANICS, MANUFACTURING AND DESIGN

A study of structural advantages of composite Materials over conventional Materials, considering high strength-to-weight and stiffness-to-weight ratios. Fiber reinforced, laminated and particulate Materials are analyzed. Response of composite structures to static and dynamic loads, thermal and environmental effects, and failure criteria are studied.

ME6551 CERAMIC SCIENCE AND TECHNOLOGY

Introduction : traditional ceramics, new ceramics, new uses for ceramics, classification of ceramics, structural ceramics, functional ceramics, characteristics of ceramic solids; Ceramic phase equilibrium diagrams : Al_2O_3 - SiO_2 system, MgO-Al_2O_3-SiO_2 system, non-equilibrium phases; Glasses : glass formation, glass structures, miscibility gaps in oxide systems, glass ceramic materials, phase separtion in glasses; Properties of ceramics : thermal, mechanical, electrical and magnetic properties; Production of ceramic components : selection of raw materials, manufacturing processes, control of microstructure, important application; Structural ceramics :

oxides, carbides, nitrides and borides; Electroceramics : electrical and dielectric properties, insulators, superconductors; Magnetic ceramics : soft and hard ferites; Refractories : classification and applications; Properties of refractoris : thermal conductivity, thermal stability, hot modulus of rupture, erosion etc.; Production of refractories : refractory shapes, selection and processing of raw materials, manufacturing processes, special techniques like fusion casting, porous refractories; Selection of refractories : alumino-silicates, silica, zirconia, magnesite, forsterite, carbon and other special refractories; refractory failures and their causes.

ME6553 METAL CASTING AND JOINING
Casting: Plane front solidification of single phase alloys, interface stability, Czochralski growth, growth of single crystals of high perfection, cellular solidification, cellular-dendritic transition, plane front solidification of polyphase alloys, macro- and micro-morphology of eutectic growth, growth of graphite in cast irons, some problems in solidification of polyphase alloys, inclusions - their formation and distribution; Rheocasting, thixocasting, electroslag casting, casting of composites.
Welding: Heat flow conditions around welds; metallurgical effects of welding, defects in welds, heat affected zone-grain size, cracking and corrosion characteristics of welds; metallurgical aspects of fusion welding; semi-solid and solid state welding, weld defects control and inspection; joining of ceramics and plastics; design of weldments.

ME6593 MATERIALS SCIENCE LAB II
Sintering and heat treatment furnaces, Thermocouple calibration**,** Fabrication and testing of composites**,** Nano-composites, Wear analysis, Welding of stainless steel, studies and experiments on Micro Machining Center, Unconventional machining , Porosity studies, Study of solidification software such as Pro-Cast, computational design of gating system, Commercial CAD/CAM softwares.

ME6521 THERMODYNAMICS OF MATERIALS
Introduction and important thermodynamic functions: Laws of thermodynamics - enthalpy, heat capacity, entropy, free energy and their interrelationships; Solutions - chemical potential, Raoult/Henry's law, Gibbs-Duhem equations, activity determination, properties of different solutions, quasichemical theory; Heterogeneous systems -equilibrium constants, Ellingham-Richardson diagrams, predominant area diagrams; Evolution of Phase diagrams-phase rule, free-energy-composition diagrams, solidus-liquidus lines, retrograde solidus; Interfaces - energy, shape, segregation at external and internal interfaces; solid electrolytes; Effect of high pressure on phase transformations; Point imperfections in crystalline solids-elementary and compound crystals.

ME6522 POWDER AND SINTERED PARTS
scope of powder metallurgy industries- PM process- versatility and benefits of Powder Metallurgy- Powder production techniques- Powder properties and their characteristics- Powder conditioning- Compaction-.; effect of variables on densification in single component system-.; effect of variables on densification in single component system- Sintering-stages- Model studies; Powder shrinkage experiments; Sintering diagrams and sintering anomalies- Products of PM

ME6523 NUCLEAR METALLURGY
Fundamentals of Nuclear Engineering- Manufacture of fuel rods, Extraction and fabrication techniques-Cladding Materials- Coolant Materials- Reactor Vessels, Requirements and types of material used for containing vessel fabrication, Shielding Materials, Corrosion of reactor components, Radiation damage and its control.

ME6524 SCIENCE OF SOLIDIFICATION PROCESS
Phase equilibrium- Thermodynamics and stability of phases- Gibbs rule and application- Thermodynamics of solidification- Hierarchy of equilibrium, Local Interface equilibrium, Interface non-equilibrium, Macro scale Phenomena- Mathematics of diffusive transport, Macro mass Transport-solute diffusion controlled segregation, analysis of solute redistribution- Macro modeling of solidification- Role of kinetics, heterogeneous and homogeneous kinetics- Kinetics of solid-fluid reaction- Solid state diffusive transformation- Mechanism of transformation.

MEE6525 CHARACTERIZATION OF MATERIALS
crystal structure determination - experimental methods - Macro and micro examination of metals- specimen preparation -- qualitative and quantitative examination- Magnetic resonance- NMR & NQRanalysis of the phenomenon – experimental methods.

ME6526 CORROSION SCIENCE AND TECHNOLOGY
Corrosion: electrochemical principles- General characteristics of electrochemical corrosion- Activation controlled kinetics and concentration polarization- Corrosion of materials in natural environments- Localized corrosion damages and materials failure- Corrosion failure of ceramic materials- Corrosion degradation of concrete. Environmental degradation and corrosion of polymer materials- Methods for protection of materials-Corrosion testing, control and monitoring

ME6527 HEAT TREATMENT TECHNOLOGY

Heat treatment principles, Time-temperature parameters of a heat treatment process- heat treatment defects and their rectification, modernisation of heat treatment processes- Heat Treatment of steels: Nucleation and growth of austenite on heating steel- Heat treatment of cast iron- classification of furnaces based on heat sources- Constructional and working features of furnaces- Reheating furnaces.

DEPARTMENT OF MECHANICAL ENGINEERING

Detailed Syllabi for the M.Tech. Programme in MATERILS SCIENCE AND TECHNOLOGY

ME6501 MECHANICAL BEHAVIOUR OF MATERIALS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hours)

Concepts of crystals, Plastic deformation by slip and twinning, Slip systems in FCC, BCC and HCP lattices, Critical resolved shear stress for slip, Theoretical shear strength of solids, Stacking faults and deformation bands. Observation of dislocations, Climb and cross slip, Dislocations in FCC and HCP lattice, Partial dislocations, Stress fields and energies of dislocations, Forces between dislocations, Interaction of dislocations, Dislocation sources and their multiplications.

Module II (11 hours)

Strengthening from grain boundaries, Grain size measurements, Yield point phenomenon, Strain aging, Solid solution strengthening, Strengthening from fine particles, Fiber strengthening, Cold working and strain hardening, Annealing of cold worked metal. Fracture in metals, Griffith theory of brittle fracture, Metallographic aspects of fracture, Fractography, Dislocation theories of brittle fracture, Ductile fracture, Notch effects, Strain energy release rate in fracture, Fracture toughness and design.

Module III (11 hours)

Fatigue of metals, The S-N curve, Low cycle fatigue, Fatigue crack propagation, Effect of stress concentration on fatigue, Size effect, Surface effects and fatigue, Fatigue under combined stresses, Effects of metallurgical variables and fatigue, Corrosion fatigue, Design for fatigue, Effect of temperature on fatigue. Creep and stress rupture, Creep curve, Stress rupture test, Mechanism of creep deformation, Activation energy for steady state creep, Superplasticity, Fracture at elevated temperature, Creep resistant alloys, Creep under combined stresses.

Module IV (10 hours)

Tension test, Stress-strain curves, Instability in tension, Ductility measurement, Effect of strain rate, temperature and testing machine on flow properties, Stress relaxation testing, Notch tensile test, Anisotropy of tensile properties. Hardness test, Brinnel, Rockwell and Vickers hardness, flow of metal under the indenter, relationship between hardness and flow curve, micro hardness testing, Hardness at elevated temperatures.

References

1. Dieter M. George, Mechanical Metallurgy, McGraw- Hill Inc., 2001.
2. Deformation and fracture mechanics, Richard W Hertzberg John Wiley & Sons
3. Mechanical behaviour of Materials, Frank A McCLINOCK and ALI S ARGON
4. Physical Metallurgy Principles, Reed Hill and Robert E, East West Press
5. Structure and properties of Materials, Hyden W. M. Vol. 3, McGraw Hill
6. Plastic deformation of Metals , Honeycombe, Arnold Press.

ME6502 FERROUS AND NON-FERROUS METALLURGY

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9 hours)

Ferrous Foundry: Melting units – cupola and its operation – design of cupola – charge calculation – electric arc furnace and induction furnace – design, fabrication and control of composition – selection – recent developments.

Module II (9 hours)

Solidification of Metals: General thermodynamic and kinetic considerations – rate of reaction – Arrehnius equation – activation energy – process of nucleation and growth – thermodynamical theory and nucleation – homogeneous and heterogeneous nucleation in solids – growth of new phase in solution – dendritic and cellular growth – freezing of ingots.

Module III (12 hours)

Cast Iron Metallurgy: Details of various cast iron – casting characteristics and mechanical properties – effect of various elements in cast irons – trace elements – type of graphites – sizes – solidification – nucleators – cooling rate – growth process – inoculants in mould process – theory of inoculation – chill testing and composition control – effect of alloying elements – fluidity – inverse chill – sub-surface blow holes – dispersed shrinkage porosity – specification of cast iron – malleable iron – black heart – composition control – S. G. iron – production – properties – treatment and applications.

Module IV (12 hours)

Steel and Non-Ferrous Metallurgy: Composition – structure – Fe-Fe C diagram – solidification process – effect of structure on properties – heat treatments of castings – liquid quench and temper – alloy steels – measurements of hardenability and its significance – production – heat treatment - solidification of steels. General demand survey of non-ferrous metals and alloys - melting units – properties of liquid metal and their significance in foundry practice – oxidation – solution of gases in metals – fluidity – hot tear – shrinkage – grain refinement – modification – various types of defects in non-ferrous alloys – details of aluminium, copper and magnesium base alloys.

References

1. Solidification process – Flemings
2. Cupola practice and Cast Iron – A F S Publication
3. An Introduction to the Solidification of Metals – W. G. Winegard
4. Non Ferrous Foundry Metallurgy – Murphy
5. Metallurgy of Non Ferrous Metals – W. H. Dennis
6. Principles of Metal Casting – Geine, Loper & Rosenthal

MA6001 MATHEMATICAL METHODS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 Hours)

Linear Algebra: Vector spaces, Basis, Dimension, Inner product spaces, Gram-Schmidth Process, Linear Transformations, Range and Kernel, Isomorphism, Matrix of transformations and Change of Basis.

Module II (11 Hours)

Series Solutions of ODE and Sturm-Liouville Theory: ,Power series solutions about ordinary point, Legendre equation and Legendre polynomials, Solutions about singular points; The method of Frobenius, Bessel equation and Bessel Functions. Sturm-Liouville problem and Generalized Fourier series.

Module III (10 Hours)

Partial Differential Equations: First order PDEs, Linear equations, Lagrange method, Cauchy method, Charpits method, Jacobi method. Second order PDEs, Classifications, Formulation and method of solutions of Wave equation, Heat equation and Laplace equation.

Module IV (11 Hours)

Tensor Calculus: Line, area and volume integrals, Spaces of N-dimensions, coordinate transformations, covariant and mixed tensors , fundamental operation with tensors, the line element and metric tensor, conjugate tensor, Christoffel's symbols , covariant derivative.

References

1. D. C. Lay: Linear Algebra and its Applications, Addision Wesley, 2003.
2. F. G. Florey: Elementary Linear Algebra with Application, Prentice Englewood, 1979.
3. K. Hoffman and R. Kunze: Linear Algebra P. H. I., 1971.
4. W. W. Bell: Special Functions for Scientist's and Engineers, Dover Publications, 2004.
5. Sokolnikoff and Redheffer – Mathematics of Physics and Engineering. 2nd edition. McGraw Hill, 1967.
6. Ian Sneddon, Elements of Partial Differential Equations, McGraw Hill International ,1985.
7. B. Spain: Tensor Calculus, Oliver and Boyd, 1965.
8. J. Irving and N. Mullineux: Mathematics in Physics and Engineering, Academic Press, 1959.
9. Shepley L Ross,Differential Equations, JohnWiley&Sons, Third Edition, 2004.
10. L.A.Pipes and L.R. Harwill: Applied Mathematics for Engineers and Physicists, Mc Graw Hill, 1971.
11. M.A. Akivis and V.V Goldberg, An Introduction to Linear Algebra and Tensors, Dover Publications, 1997.

PH6001 PHYSICS OF MATERIALS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hours)

Quantum Mechanics – Introduction - Wave nature of matter, wave particle duality, operators. Schrodinger's wave equation –wave function and its properties. Uncertainty principle – applications of Schrodinger's equation to general problems.

Module II (10 hours)

Classification of condensed matter-crystalline and noncrystalline solids, liquids, Crystalline solids-Bonding and internal structure-K space, Momentum space, Reciprocal lattice and lattice vector-X-ray, Neutron and electron diffraction of waves by crystals, Bragg's law in direct and reciprocal lattice-Structure factor-Brillouin zones-Excitations in solids. Excitons and Polarons.

Module III (12 hours)

Dependence of electron energy on wave vector, E-K diagram, Free electron theory of metals, Density of states, Thermal and electrical transport properties, Fermi surface, Energy spectra of atoms, molecules and solids, formation of energy bands, Electrons in periodic potential. Bloch theorem. Electron states and classicication into insulators, conductors, semimetals. Effective mass and concept of holes.

Glassy state and glass transition temperature, crystallization and melting, phase transformations: first order and second order phase transformations. Arrhenius type dependence- Measurement techniques for glass transition temperature and heat capacity-Differential scanning calorimetry.

Module IV (11 hours)

Mesoscopic physics, Quantum wire, well and dot. Fundamentals of nano technology: size, and interface effects, Quantum confinement and Coulomb blockade

Superconductivity. Meissner effect, London equation, Type I and II superconductors, Superconducting band gap, Cooper pairs, flux quantization. BCS theory (qualitative). High temperature superconductors, Conducting polymers.

References

1. Eisberg Resnik: Quantum Physics, Wiley (2006)
2. M A Omar: Elementary Solid State Physics, Addison Wesley (2007)
3. Kittle, C: Introduction to Solid State Physics, Wiley (2007)
4. CM Kachhava: Solid State Physics, TMH (2005)
5. Rosenberg: Introduction to Solid State Physics, Oxford University Press (1995)

ME6591 MATERIALS SCIENCE LAB I

L	T	P	C
0	0	3	1

Specimen preparation and microstructure studies using Metallurgical and Scanning electron Microscope, Testing of metals –hardness, fatigue, Surface roughness measurement, study of Coordinate measuring machine, Metrology, NDT testing such as ultrasonic, die-penetrant and magnetic particle techniques, Testing of weldments. Use of software in materials engineering- Solid modeling exercises on advanced Softwares like 'I-DEAS' 'Pro-Engineer', 'CATIA', Exercises on finite element analysis using ANSYS and ABAQUS software.

ME6592 SEMINAR

L	T	P	C
0	0	3	1

Each student shall prepare a seminar paper on any topic of interest based on the core/elective courses being undergone in the first semester in the field of specialization – Material Science. He/she shall get the paper approved by the Programme Coordinator/Faculty Advisor/Faculty Members in the concerned area of specialization and present it in the class in the presence of Faculty in-charge of seminar class. Every student shall participate in the seminar. Grade will be awarded on the basis of the student's paper, presentation and his/her participation in the seminar.

ME6511 COMPOSITE MATERIALS:
MECHANICS, MANUFACTURING AND DESIGN

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9 hrs)

Introduction: Classification of composite materials and geometric morphology, advanced metal, ceramic, and polymer matrix composites, reinforcing fibers, interfaces, manufacturing of composites.

Module II (11 hrs)

Behavior of unidirectional(UD) composites: review of the theory of elasticity, Hooke's law for generally anisotropic elastic solids, lamina stress-strain relationships, strength of UD composites, failure modes, short fiber composites, theories of stress transfer, analysis of orthotropic lamina, stress strain relationships, strengths.

Module III (12 hrs)

Analysis of laminated composites, stress-strain variation, synthesis of stiffness matrix, construction and properties of special laminates, determination of laminae stresses and strains, analysis of laminates after initial failure, ply-by-ply failure analysis of laminates, laminate analysis through computers, hygrothermal stresses, fatigue failure mechanisms, damage accumulation, methods of fatigue analysis and design, experimental characterization of composites, interlaminar stresses, fracture mechanics of fiber composites

Module IV (10 hrs)

Introduction to composite structures; effective moduli and rigidities of compound laminates, properties of composite sections and stiffened panels, introduction to laminated beams, plates, and shells, introduction to composite structural design.

References

1. B.D. Agarwal and L.J. Broutman, "Analysis and Performance of Fibre Composites", John Wiley & Sons Inc.
2. Ronald F. Gibson, "Principles of Composite Material Mechanics", McGraw Hill.
3. Stephen W Tsai, H. Thomas Hahn, "Introduction to Composite Materials", Technomic Publishing Company
4. R. M. Jones, "Mechanics of Composite Materials", McGraw-Hill.
5. D. Hull and T. W. Clyde, "An Introduction to Composite Materials", Cambridge University Press.
6. Mel M Schwartz, " Composite Materials Handbook", McGraw-Hill Inc.

ME6512 CERAMIC SCIENCE AND TECHNOLOGY

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (8 hours)
Introduction: definition of ceramic materials; overview of physical differences from metals; raw materials; relationship to geology. Structure-Crystals-potentials and Madelung constant-ionic sizes and Pauling's Rules-oxide structures-silicate structures-Glasses-polymerization indices-radial distribution functions-quasi-crystalline models

Module II (15 hours)
Point Defects-mechanistic models-point defect thermodynamics: Kroger-Vink analysis-intrinsic (thermal), extrinsic (doping/impurities) and non-stoichiometric (activity-dependent) defects-defects in ternary compounds–spinel, oxide superconductors. Line Defects (Dislocations)-crystallography-jogs, kinks and electrical problems Surfaces and Interfaces Grain Boundaries-crystallography and structure-electronic and chemical segregation Interfacial energies-curved surfaces-micro-structural (textural) equilibrium Atomic Mobility
Diffusion and Atomic Fluxes: Fick - Einstein Relationship-Chemical Diffusion in Ionic Solids-Darken analysis (uncoupled fluxes)-Nernst-Planck analysis (coupled fluxes)-Relationship to Point Defects: Activity Dependence-Grain Boundary and Dislocation (Pipe) Diffusion-Diffusion-induced grain boundary migration.
Phase Equilibria: Gibbs Phase Rule-Types of Phase Diagrams (I, II, III)-Experimental Control of Intensive Thermodynamic Variables-Ternary Phase Diagrams-liquidus diagrams and isothermal sections-divariant and monovariant equilibrium-solid solutions.

Module III (7 hours)
Processing of ceramic material: Homogeneous/Heterogeneous Reactions: Definitions-Heterogeneous Reactions-transport through a planar boundary layer: slip-casting, interdiffusion and compound formation, oxidation (Ellingham analysis of force)-transport through a fluid phase: thermal decomposition, chemical vapor deposition-transport in particulate systems: calcining, powder reactions (Jander analysis), Ostwald ripening,Solid State Reactions, Powder Processing, Solid State Sintering-driving forces-models: conservation of driving force-Grain Growth and Grain Boundary Mobility-Liquid-Phase Sintering

Module IV (10 hours)
Properties of Ceramics: Mechanical Properties-Creep: High-Temperature Properties and HIP Processing-Brittle Failure: Statistical Design Strength-Thermal Shock/Anisotropy-Induced Microcracking-Composites
Optical and Dielectric Properties

References

1. Y.M. Chiang, D. Birnie and W.D. Kingery, Physical Ceramics: Principles for Ceramic Science and Engineering, John Wiley & Sons, New York, 1997.
2. Kingery, W. D., H. K. Bowen & D. R. Uhlmann, Introduction to Ceramics; Second Edition, John Wiley & Sons, New York, 1976.
3. Barsoum, M., Fundamentals of Ceramics, McGraw Hill, New York, 1997.
4. West, A. R., Solid State Chemistry and its Applications, John Wiley & Sons, Chichester, 1984.
5. CRC Handbook of Chemistry and Physics, CRC Press, Boca Raton, FL.
6. ASM International Handbook Committee, Engineered Materials Handbook; Volume Ceramics and Glasses, ASM International, Metals Park, OH, 1991.
7. Bergeron, C. G. and S. H. Risbud, Introduction to Phase Equilibria in Ceramics, American Ceramic Society, 1984
8. Devereux, O. F., Topics in Metallurgical Thermodynamics, Wiley, 1983
9. Doremus, R. H., Glass Science, Wiley, 1973 (1^{st} edition), 1994 (2^{nd} edition)
10. Green, D. J., An Introduction to the Mechanical Properties of Ceramics, Cambridge Univ. Press, 1998
11. Kelly, A. and G. W. Groves, Crystallography and Crystal Defects, Addison-Wesley, 1970
12. McHale, A. E., Phase Diagrams and Ceramics Processes, Chapman and Hall, 1998
13. McMillan, P. W., Glass Ceramics, Academic Press, 1969 (1^{st} ed), 1979 (2^{nd} ed)
14. Paul, A., Chemistry of Glass, Chapman and Hall, 1982 (1^{st} ed), 1990 (2^{nd} ed)
15. Pauling, L., The Nature of the Chemical Bond, Cornell Univ. Press, 1960 (3^{rd} ed)

ME6513 METAL CASTING AND JOINING

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9 hours)

Foundry – Sand casting – Pattern layouts – Parting lines – Mould and Core making – Heat transfer between metal and mould – Solidification of casting – Freezing of pure metal – Homogeneous and Heterogeneous nucleation – Crystal growth – Freezing of alloys.

Module II (12 hours)

Design of gating system – Theoretical consideration – Directional solidification – Design of risers – Modulus – Caine's and shape factor methods – Use of CAD in the design of gating and risering – Application of chills.
Special Moulding processes – Shell moulding – Investment casting – Die casting – Centrifugal casting – High Pressure moulding – Casting defects and their remedies – Fettling and testing of casting.

Module III (10 hours)

Metal Joining – Classification – Welding power sources – Arc and Arc characteristics – Behaviour of arc with variation in current and voltage – Welding electrodes – ISI specifications for electrodes – Electrode selection – Newer welding processes such as Plasma arc, Laser beam, Electroslag, and Ultrasonic welding, Joining by brazing, Soldering and Adhesive bonding

Module IV (10 hours)

Welding Metallurgy – Heat flow in welding – Metallurgical transformation in and around weldment – Implication of cooling rates – Heat affected zone (HAZ) – Weldability of plain carbon steels, Stainless steels, Cast iron, Aluminium and its alloys. Design of weldments – Joint design – Residual stresses and distortion – Testing of welded joints – Destructive Tests and Non-destructive tests (NDT)

References

1. Heine, Loper & Rosenthal, Principles of Metal Casting, TMH Publications.
2. P.C. Mukherjee, Fundamentals of Metal Casting technology, Oxford & I.B.H. Publications.
3. Jail P. L, Principles of Foundry Technology, T.M.H. Publications.
4. Udin, Funk & Wulf, Welding for Engineers, John Wiley and Sons.
5. ASM Metals Hand Book.
6. J.L. Morris, Welding Process and Procedures.

CY6001 POLYMER SCIENCE AND TECHNOLOGY

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (11 hours)

Nanofiller synthesis, applications, Polymer nanocomposites, introduction, particulate and fibre modified nanocomposites, matrices and fibres, polymer- filler interphase, pull- out strength, effect of various treatments.

Module II (11 hours)

Mechanics of polymer nanocomposites, , nterfacial adhesion and charecterisation, factors influencing the performance of nanocomposites, physical and functional properties.

Nanocomposite farication,matrices, methods, additives, moulding processes.

Module III (10 hours)

Characterisation of polymer / nanofillers systems, Rheological measurements, Processing characteristics, mechanical, thermal, optical, electrical features, , solvent resistance, ageing.

Module IV (10 hours)

Testing of nanocomposites, Importance of standards and standards organizations, processability and performance, tensile stress/ strain, tear tests, rebound resilience, friction, creep, fatigue, melt flow index, viscosity test, thermal analysis such as TGA, TMA, and DSC.

References

1. Fred W. Billimeyer, Jr, Text Book of Polymer Science, third edition, Wiley Interscience Publication, 1994.
2. Joel R. Fried,mPolymer Science and Technology, Prentice- Hall, Inc. Englewood Cliffs, N. J., USA, 2000.
3. Hand book of Elastomers: New Developments and Technology (Eds. A. K. Bhowmic and H. C. Stephense), Marcel- Dekker Inc., New York, 1995.
4. D. R. Paul and S. Newman, Polymer Blends, Academic Press, New York, 1978.
5. M. J. Folkes, Short Fibre Reinforced Thermoplastics, John Wiley, New York, 1982.

ME6593 MATERIALS SCIENCE LAB II

L	T	P	C
0	0	3	1

Sintering and heat treatment furnaces, Thermocouple calibration, Fabrication and testing of composites, Nano-composites, Wear analysis, Welding of stainless steel, studies and experiments on Micro Machining Center, Unconventional machining , Porosity studies, Study of solidification software such as Pro-Cast, computational design of gating system, Commercial CAD/CAM softwares.

ME6594 TERM PAPER/MINI PROJECT/INDUSTRIAL TRAINING

L	T	P	C
0	0	-	1

Students are free to select any one assignment from the following term paper/mini project/industrial training.

Term Paper: Prepare a review paper on any topic from Material Science and Technology with the individual analysis and comments.

Mini project: Students can select any project and work under the guidance of any teaching staff in the department. End of the semester, each student has to submit a thesis report.

Mini Project Work is evaluated by the department as per M. Tech. regulations.

Industrial Training: Those who are opting for industrial training, has to undergo a minimum of four weeks training in well established industries during the summer vacation after the first two semesters. He has to submit a comprehensive report on his training to the department and the same is evaluated as per M. Tech. regulations.

ME7595 PROJECT WORK

L	T	P	C
0	0	0	8

The student will be encouraged to fix the area of the project work and conduct the literature review during the second semester itself. The project work starts in the third semester. The topic shall be research and development oriented. The project can be carried out at the institute or in an industry/research organization. They are supposed to complete a good quantum of the work in the third semester. There shall be evaluation of the work carried out in the third semester.

ME7596 PROJECT WORK

L	T	P	C
0	0	0	12

The project work started in the third semester will be extended to the end of the fourth semester. The project can be carried out at the institute or in an industry/research organization. Students desirous of carrying out project in industry or other organization have to fulfil the requirements as specified in the "Ordinances and Regulations for M. Tech.". There shall be evaluations of the project work by a committee constituted by the department and by an external examiner.

Regulations for M. Tech. under the section - Project Work in Industry or Other Organization
At the end of the third semester, the students' thesis work shall be assessed by a committee and graded as specified in the "Ordinances and Regulations for M. Tech.". If the work has been graded as unsatisfactory, the committee may recommend a suitable period by which the project will have to be extended beyond the fourth semester. At the end of the fourth semester, the student shall present his/her thesis work before an evaluation committee, which will evaluate the work and decide whether the student may be allowed to submit the thesis or whether he/she needs to carry out additional work. The final viva-voce examination will be conducted as per the "Ordinances and Regulations for M. Tech."

ME6521 THERMODYNAMICS OF MATERIALS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (8 hours)

First Law of Thermodynamics, heat, work, heat capacity, enthalpy and internal energy, Hess' Law- and Second Law of Thermodynamics – Entropy and Criterion for Equilibrium – Statistical interpretation of entropy – Boltzmann equation.

Module II (11 hours)

Auxiliary Functions – Thermodynamic Relations – Maxwell's Equations – Gibbs - Helmholtz Equation – Examples – Heat capacity, enthalpy, entropy and the third law of Thermodynamics.
Phase Equilibrium in a One – Component System- Solid – Solid Equilibria – examples – Behaviour of gases – The van der Waals Gas – Non ideal gases – examples.

Module III (11 hours)

Behaviour of Solutions – Raoult's and Henry's Law, Gibbs – Duhem Equation – Non ideal solutions – Regular Solutions – Subregular Solutions – Examples.
Gibbs Free Energy – Composition and Phase Diagrams of Binary Systems – Criteria for Phase Stability – Phase Diagrams of Binary Systems.

Module IV (12 hours)

Reaction equilibrium in a Gas mixture and the equilibrium constant – Effect of Temperature and pressure – Reaction equilibrium in a system containing pure condensed phases and a Gas phase – Ellingham Diagrams – Effect of phase transformations – examples – Criteria for Reaction equilibrium in systems containing components in condensed solution – Gibbs Phase rule – Solubility of gases in metals – examples.
Electrochemistry – Formation Cells – Concentration Cells – Pourbaix Diagrams.

References

1. Gaskell David R., Introduction to the Thermodynamics of Materials, 3rd ed., Taylor & Francis Publishers, 1995.
2. David V. Ragone, Thermodynamics of Materials, Volume I, J. W. Wiley 1995.
3. Thermodynamics in Materials Science, By Robert T. DeHoff, McGraw-Hill, 1993.
4. Stoichiometry and Thermodynamic Computations in Metallurgical Processes, By. Y.K. Rao, Cambridge University Press, 1985.

ME6522 POWDER AND SINTERED PARTS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (12 hours)

Introduction : scope of powder metallurgy industries, PM process, comparison of powder metallurgy process with alternate near net shape producing technologies (viz. casting, forging and machining), versatility and benefits of Powder Metallurgy, problems of Indian powder metallurgy industries, unique applications of powder metallurgy process, Secondary operations, Powder production techniques-mechanical, atomisation, chemical-reduction and carbonyl and electro-chemical processes;

Module II (8 hours)

Powder properties and their characteristics, Particle size distribution, Types of distribution function, Sampling of powders-sieve analysis, Microscopy, Sedimentation analysis; Specific surface and other technological properties; Powder conditioning; relation between characterisation of the powders and method of production, pre-compacting processes, mixing, milling, lubricant addition etc

Module III (10 hours)

Compaction : classification, stages of compaction, effect of different variables on the density and stress distribution in the green compacts, compacting processes, Hot Iso-static Pressing (HIP), Cold Iso-ststic Pressing; Pressing equipments and tooling ;defects in compacts; alternate shaping processes, : powder rolling, slip casting, injection molding, Explosive molding etc.; effect of variables on densification in single component system.

Module IV (12 hours)

Sintering-stages, single component, material transport mechanisms; Model studies; Powder shrinkage experiments; Sintering diagrams and sintering anomalies, Multi-component sintering-solid phase and liquid phase, infiltration, activated sintering, reaction sintering, hot consolidation of powders, post-sintering treatment; evolution of microstructure; Sintering atmospheres and equipments; Production routes in practice; Products of PM- Automobile components, Bearings, Cutting tools-HSS and Carbides, Ceramic components etc.

References

1. An introduction to Powder Metallurgy by F Thummler and R Oberacker, The Institute of Materials, The University Press, Cambridge Great Britain. ISBN 0-901716-26-X
2. ASM Handbook: Powder Metal Technologies and Applications (ASM Handbook, Vol 7).

ME6523 NUCLEAR METALLURGY

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (12 hours)

Fundamentals of Nuclear Engineering, Radiation, Fission, Reactor and reactor elements, Fuel Roads, Manufacture of fuel rods, Extraction and fabrication techniques for uranium and thorium, Reprocessing of uranium oxide fuel elements.

Module II (10 hours)

Cladding Materials, Requirements of cladding material, Aluminium, Stainless steel and Zirconium alloys, their preparation and fabrication.

Module III (10 hours)

Coolant Materials, Use of liquid metals, liquid corrosion. Production and use of heavy water, beryllium; reactor grade, graphite for reactor components, control rods.

Module IV (10 hours)

Reactor Vessels, Requirements and types of material used for containing vessel fabrication, Shielding Materials, Corrosion of reactor components, Radiation damage and its control.

References

1. J. C. Wright – Metallurgy of nuclear Metals.
2. Weinstein, Boltax and Langa – Nuclear Engineering Fundaments
3. S. Glasstone, A, Sesonski – Nuclear Reactor Engineering
4. S. Glasstone – Nuclear Reactor Engineering: Rector Systems Engineering
5. J R. Lamarsh - Introduction to Nuclear Engineering -

ME6524 SCIENCE OF SOLIDIFICATION PROCESS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hours)

Phase equilibrium: Introduction, Thermodynamics and stability of phases, Classification of phase transformations, Order of transformation, Gibbs rule and application, Phase diagrams construction and interpretation. Liquid-solid transformation: Nucleation, homogeneous and heterogeneous, Growth continuous and lateral; Interface stability; Alloy solidification cellular and dendritic, Eutectic, off-eutectic, peritectic solidification; Welding, casting and rapid solidification.

Module II (10 hours)

Length scale, Thermodynamics of solidification- equilibrium, Undercooling, Hierarchy of equilibrium, Local Interface equilibrium, Interface non-equilibrium, Macro scale Phenomena-formation of macrostructures, relevant transport equations. Mathematics of diffusive transport, Macro mass Transport-solute diffusion controlled segregation, analysis of solute redistribution, Fluid flow controlled segregation, macro energy transport, governing equations, boundary conditions, Analytical solutions for steady state and non-steady state casting solidification. Macro modeling of solidification: numerical approximation methods. Multi scale phenomena and interface Dynamics.

Module III (10 hours)

Role of kinetics, heterogeneous and homogeneous kinetics, Role of heat & mass transfer in metallurgical kinetics, rate expression, Effect of Temperature and concentration on reaction kinetics: effect of temperature (Arrhenius Equation), Effect of concentration (order of a reaction), significance and determination of activation energy, Kinetics of solid-fluid reaction: kinetic steps, rate controlling step, definition of various resistances in series, shrinking core model, chemical reaction as rate controlling step, Product layer diffusion as rate controlling step, Mass transfer through external fluid film as rate controlling step, heat transfer as the rate controlling step.

Module IV (12 hours)

Solid state diffusive transformation: Classification, Nucleation and growth - homogeneous and heterogeneous mechanism, Precipitate growth under different conditions, Age hardening, Spinodal decomposition, Precipitate coarsening, Transformation with start range diffusion, Moving boundary transformations, recrystallization, grain growth, eutectoid transformation, discontinuous reactions. Pearlitic and bainitic transformation: Factors influencing pearlitic transformation, Mechanism of transformation, Nucleation and growth, Orientation relationship, Degenerate pearlite. Bainite mechanism of transformation, Orientation relationships, Surface relief, Classical and non-classical morphology, Effect of alloying elements.

References

1. Doru Michael Stefanescu, 2002, Science and Engineering of Casting Solidification, Kluwer Academic/Plenum publishers
2. Oystein Grong, 1997, Metallurgical modeling of welding, 2nd Edn, Institute of materials.
3. Koenraad Janssens et al. 2007, Computational materials Engineering –An Introduction to microstructure evolution, Academic Press
4. Gaskell David R., Introduction to the Thermodynamics of Materials, 3rd ed., Taylor & Francis Publishers, 1995.

MEE6525 CHARACTERIZATION OF MATERIALS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (12 hours)

X- ray diffraction -- Bragg's condition -- Laue treatment -- reciprocal lattice—intensity of diffracted beam -- crystal structure determination -- atomic scattering factor --geometrical structure factor for s.c, f.c.c and b.c.cc structures -- experimental methods – Laue, rotating crystal and powder photograph methods – estimation of stress, texture and other defects -- electron diffraction -- neutron diffraction.

Module II (10 hours)

Macro and micro examination of metals – specimen preparation -- qualitative and quantitative examination – optical microscopy – transmission and scanning electron microscopy, atomic force microscopy, thermal characterisation techniques.

Module III (10 hours)

Atomic absorption spectroscopy –Activation technique – Mossbauer effect – resonance fluorescence – Temperature dependence -- applications of Mossbauer effect – isomer shift – quadrupole splitting – hyperfine splitting.

Module IV (10 hours)

Magnetic resonance – NMR – analysis of the phenomenon – experimental method – NMR spectra – applications – NQR – analysis of the phenomenon – NQR spectra – applications to study of deformed metals and crystalline electric field – ESR -- phenomenon – experimental study – ESR spectra – applications.

References

1. **Solid** State Physics by S.O Pillai ,New Age International, 5th edn, 2001
2. Straughan and Walker, Spectroscopy – Vols. I & II, Chapman & Hall
3. R L Singhal, Solid State Physics, Kedar Nath Ram Nath & Co., Meerut, 7th edn, 2001.
4. Srivastava and Srinivasan, Science of Engineering Materials by Wiley Eastern Ltd., 1991.
5. Agrawal, Introduction to Engineering Materials, Tata McGraw -- Hill, 1988.

ME6526 CORROSION SCIENCE AND TECHNOLOGY

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hours)

Corrosion: electrochemical principles, Electrode potential, Nernst equation. oxy-reduction potentials; General characteristics of electrochemical corrosion, electrochemical heterogeneity of metallic materials, models of corrosion cell; Corrosion thermodynamics – Pourbaix diagrams; Polarization of the corrosion cell; Activation controlled kinetics and concentration polarization, Evans diagrams, partial corrosion reactions- anodic dissolution of metals; Cathodic reactions – oxygen reduction and hydrogen evolution.

Module II (10 hours)

Corrosion of materials in natural environments; Atmospheric corrosion – general characteristics, mechanism and prevention; soil corrosion – general characteristics, mechanism and prevention. Localized corrosion damages and materials failure- passivity and transpassivity of metals, breakdown of passivity and pitting corrosion. Stress – corrosion cracking of materials. Intergranular corrosion failure.

Module III (10 hours)

Corrosion failure of ceramic materials; mechanisms of corrosion of ceramics, effect of chemical, phase composition and structure on corrosion resistance. Corrosion degradation of concrete. Environmental degradation and corrosion of polymer materials - Destruction of polymers – types and mechanism. Effect of composition and structure on environmental degradation of polymer materials.

Module IV (10 hours)

Methods for protection of materials. Overview of corrosion prevention methods. Chemical and electrochemical surface treatment of metals. Metallic, inorganic and organic protective coatings. Application of inhibitors. Electrochemical methods for corrosion protection. Corrosion control and monitoring. Principles of material selection. Corrosion testing and monitoring.

References

1. FONTANA, Mars G, Advances in corrosion science and technology -- 1970
2. LANDOLT, Dieter, Corrosion and surface chemistry of metals -- 2007
3. UHLIG, Herbert, Corrosion and corrosion control -- 1984

ME6527 HEAT TREATMENT TECHNOLOGY

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hours)

Heat treatment principles, Time-temperature parameters of a heat treatment process; classification of heat treatment processes, heat treatment defects and their rectification, modernisation of heat treatment processes for near net shape applications and surface treatments; energy efficiency in heat treatments, design and layout of heat treatment shops.

Module II (10 hours)

Heat Treatment: Heat Treatment of steels: Nucleation and growth of austenite on heating steel – Isothermal transformation of austenite to pearlite and bainite. Annealing, normalising, tempering, marquenching and transforming – surface and case hardening of steels – hardenability and its usefulness.

Module III (10 hours)

Cast Iron, Fe-C-Si diagram, Heat treatment of cast iron, white, malleable, spheroidal cast iron – alloy cast iron. Aluminium alloys and age hardening copper alloys – reactive and refractory metals for high temperature service: Ti and Zr alloys, Ni and Co based super alloys heat treatment.

Module IV (12 hours)

Furnace: classification of furnaces based on heat sources – principles of design of recuperators and regenerators – furnace aerodynamics, heat transfer in furnaces – isothermal modelling of furnaces, heat balances.

Constructional and working features of blast furnace, cupola, reverbatory, open hearth, crucible, Induction and Arc furnaces.
Reheating furnaces – heat treatment furnaces - Materials of furnace construction, refractories and insulating materials – elements of furnace design – design of annealing furnace.

References

1. Industrial Furnaces – E. I. Kazantsev – Mir. Publications
2. Industrial Furnaces – Nortan
3. Physical Metallurgy Principles – Reed Hill
4. Elements of Physical Metallurgy – A. G. Guy
5. Heat Treatment of Steel – Gregory and Simons
6. A S M Metals Hand Book Vol.2