M.Tech (Material Science)
Course Duration : 4 Semesters (Two Years)

Eligibility: M.Sc in Physics / Chemistry or B.E / B.Tech in Mechanical, Civil, Electronics, Electrical Engineering
No. of Seats: 15

**Scheme of Examination**

**First Semester**

<table>
<thead>
<tr>
<th>Theory Paper Code</th>
<th>Paper Title</th>
<th>Hrs /wk</th>
<th>Mark (Uni. Exa m)</th>
<th>Internal Assessment</th>
<th>Hrs / Wk</th>
<th>Marks(Univ. Exam)</th>
<th>Int. Assessment</th>
<th>Practic al Paper Code</th>
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<tbody>
<tr>
<td>MS-101</td>
<td>Materials and their properties</td>
<td>4</td>
<td>100</td>
<td>50</td>
<td>3</td>
<td>75</td>
<td>75</td>
<td>MS-L1</td>
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<tr>
<td>MS-102</td>
<td>Material Synthesis/ Processing</td>
<td>4</td>
<td>100</td>
<td>50</td>
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<tr>
<td>MS-103</td>
<td>Mathematical Techniques</td>
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<td>100</td>
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<td>MS-L2</td>
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<tr>
<td>MS-104</td>
<td>Thermodynamics</td>
<td>4</td>
<td>100</td>
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<td>16</td>
<td>400</td>
<td>200</td>
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## Second Semester

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<th>Int. Assessment</th>
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<tr>
<td>MS-201</td>
<td>Characterisation and testing of Materials</td>
<td>4</td>
<td>100</td>
<td>50</td>
<td>4</td>
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<td>MS-L3</td>
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<tr>
<td>MS-202</td>
<td>Polymers</td>
<td>4</td>
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<td>MS-203</td>
<td>Biomaterials: structure and function</td>
<td>4</td>
<td>100</td>
<td>50</td>
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<td>MS-204</td>
<td>Semiconductors and superconductivity</td>
<td>4</td>
<td>100</td>
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### Third Semester

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<td>Solid State Phase Transformations</td>
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<td>100</td>
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<tr>
<td>MS-302</td>
<td>Opto-electronic materials</td>
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<td>100</td>
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<td>MS-303</td>
<td>Ceramics</td>
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<td>100</td>
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<tr>
<td>MS-304</td>
<td>Nanomaterials</td>
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<td>100</td>
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<tr>
<td>MS-305</td>
<td>Minor Project (literature survey)</td>
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<td>50</td>
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<td>450</td>
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### Fourth Semester:

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<th>Internal Assessment</th>
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<th>Marks(Univ. Exam)</th>
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<tbody>
<tr>
<td>MS-401</td>
<td>Major Project (Thesis)</td>
<td>-</td>
<td>-</td>
<td></td>
<td>20</td>
<td>350 (200+150)</td>
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<tr>
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<td></td>
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<td></td>
<td>20</td>
<td>350</td>
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Syllabus for M.Tech (Material Science)

Ist Sem

1. **Materials and their properties**

   **Material classification**: Engineering materials, their classification, metals, ceramics, polymers, advanced materials composites, structure-property-processing co-relationship as a theme of materials science.

   **Crystal structure**: space lattice, basis, crystal systems, miller indices for direction and planes, crystal structures of solids, close packed structures, crystal structure of NaCl, CsCl, Diamond, Zinc blende, Wurtzite, Rutile, Fluorite, Fullerenes, pervoskite etc. Crystal structure analysis by X-ray and electron diffraction.

   **Non Crystalline structure**: General features and classification, structure model for amorphous materials, microcrystalline chain and ring model, molecular model, structure and properties of metallic glass and amorphous semiconductors. Point defects, diffusion, dislocations.

   **Thermal Properties**: lattice vibrations, vibrations of simple lattice optical and acoustic phonons, heat capacity, thermal expansion, thermal conductivity, thermal stress in materials with example and characteristics in metals and non-metals.

   **Optical behaviour**: Interaction of radiation with matter (metals and non-metals), Phosphorscence, luminescence and optical active materials.

   **Mechanical behaviour**: deformation, slip planes and directions, shear stress, theoretical shear strength of crystals, strain hardening and recovery.

   **Electronic properties**: Free electron theory and density of states, electrical resistivity of metals and multipurpose solids, electronic specific heat. Drude and Sommerfeld theories of metals, effect of periodic lattice potential

   Reference books:
   1. Lawrence H.Van Vlack, Elements of material Science & Engg., Addison Wesley

2. **Material Synthesis/ Processing**

   **Solidification** from liquid and vapor phase, Nucleation, growth of homogeneous and heterogeneous nucleation, Interface stability, development of microstructure, super cooling, equilibrium phase diagrams, eutectic and peritectic solidification and their microstructures.

   **Foundary techniques**: sand casting, permanent mould casting, investment casting and die casting, casting defects and their inspection.

   **Forming Processes**: Fundamentals of metal forming, hot working processes, rolling, forging, cold working processes, bending, shearing, squeezing etc. Joining, welding, brazing and soldering- conventional and laser techniques.
Preparation of Materials: Crystal Growth, Amorphous materials, Nano materials, Polymers by different techniques.

Device Fabrication: Oxidation Diffusion, Ion Implantation, Metallization, Lithography and Etching, Bipolar and MOS device fabrication.

Environmental and social issues in material science: Recycling issues in material science and engineering

Reference books:
1. Principles of solidification, Bruce Chalmner, Willy.
4. Eutectic Solidification Processing, R. Elliott, Butterworth
5. K. Thyagarajan and A. Ghatak, Lasers- Theory and Applications, Mcmillan India Ltd.
6. W.D. Callister, Wiley and Sons, Materials and Engineering- An Introduction

3. Mathematical techniques

Series solution of differential equations, Power series methods, Legendre’s polynomial, Generating functions, Recurrence relations. Frobenius method, Series solution of Bessel’s differential equation, Modified Bessel’s functions, Generating functions, Recurrence relations. Equations reducible to Bessel’s equation.

Sturm Liouville’s problem, orthogonal functions, Orthogonality of eigen functions, Eigen function expansions.


Approximate and numerical solutions of PDE’s: Finite difference approximation to derivatives.

Numerical solutions of elliptic equations (Laplace and Poisson’s equations), Parabolic equations and Hyperbolic equations.

References Books:
4. Thermodynamics
Recapitulation of Equilibrium.
Thermodynamics of solutions: Partial molar quantities, Gibbs-Duhem equation, ideal and regular solutions, Partial and excess properties, Quasi-chemical model, Polynomial expressions for excess Gibbs energy of mixing for binary and higher order solutions. Multi-component dilute solutions and interaction parameters.
Chemical Equilibrium: Direction of spontaneous change in a chemical reaction, extent of reaction, stoichiometric coefficients, equilibrium constant in terms of G. Temperature and pressure dependence of equilibrium constant, homogeneous & heterogeneous equilibria.
First and second order phase transitions. Attainment of low temperature and energetics of refrigeration, adiabatic demagnetization.
Phase Equilibria: Phase rule and binary phase diagrams Free energy composition diagrams. Phase equilibrium calculations. Introduction to ternary phase diagrams, chemical reactions involving gases and solids- Ellingham diagrams, eutectics, freezing mixture, zone refining.

Reference Books:

Lab: Electrical And Magnetic Materials Lab
1. Resistivity of a semiconductor using Four Probe method.
2. Measurement of magnetoresistance of Semiconductors
3. Electron Spin resonance spectrometer
4. Dependence of Hall Coefficient on Temperature
5. Study of Dielectric constant.
6. To measure the susceptibility of paramagnetic solids by Quineck’s tube method
7. To determine the thermionic work-function of tungsten using a directly heated diode
2nd Sem

1. Characterization and testing of materials

**Introduction:** Important parameters describing the materials; need of material characterization, available characterization techniques etc.

**Quantitative image analysis:** basic measurements (grain size, particle morphology, particle size, and size distribution) and applications.

**High Vacuum:** Diffusion Pump, Turbo Molecular Pump, Gauges for measuring high vacuum.

**Powder characterization:** Important properties of powders and its measurement techniques; Determination of particle size, increase in width of XRD peaks.

**Optical microscopy:** light optics, microscope components, Scanning electron microscope: performance of SEM; Transmission electron microscopy: construction and operation of TEM, electron diffraction, image interpretation; Scanning Tunnelling Microscopy: Constant current and constant height - mode – Instrumentation; Atomic Force Microscopy: Imaging modes, Force sensor, Deflection detection; Ion Beam Techniques: Rutherford Backscattering Spectrometry (RBS), Field Ion Microscopy (FIM)

**Spectroscopic techniques:** Mass spectroscopy and X-ray emission spectroscopy (Principle and limitations) - Quadrupole mass spectrometer. Special surface techniques: Electron spectroscopy for chemical analysis (ESCA), ultraviolet photo electron spectroscopy (UPS), X ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES), Electron energy analysers, Secondary ion mass spectrometry, mass spectrometer types – Applications, Laser Raman Spectroscopy, Fourier Transform Infrared Spectroscopy, micro-Raman, Luminescence,

**Resonance methods:** NMR, Mossbauer spectroscopy,

**Surface structure and surface structure analysis:** The need for surface study. Surface chemical composition: The extension of bulk techniques to surface studies - Unit meshes of five types of surface nets - diffraction from diperiodic structures. Surface methods using electron, low energy electron diffraction (LEED), reflection high energy electron diffraction (RHEED), Scanning Probe microscope, Ellipsometry

**Thermal analytical techniques:** Principles of differential thermal analysis, differential scanning calorimetry and thermogravimetric analysis - Instrumentation - determination of transition temperature, heats of transition of plastics, metals and alloys and other materials.

**Mechanical testing:** Introduction of important mechanical properties of materials, tensile testing, hardness testing, impact testing, fatigue testing, creep testing, torsion testing.

**Non-destructive testing:** Introduction, magnetic particle testing, eddy current testing, radiography ultrasonic testing, acoustic emission testing, thermography

Reference Books:

5. B. D. Cullity, X-ray Diffraction.
6. John P. Sibilia, A guide to material characterization and chemical analysis, VCH Publishers Inc. NY, 1988

2. Polymers

Polymerisation principles and processes- step, chain and other polymerizations, polymer kinetics, polymerization techniques. 

Polymer manufacturing- unit operations, polymer reactors, polymer isolation, handling and storage. 

Polymer structure and properties, polymer characterization, polymer modification, compounding and fabrication, testing, product design, applications and processing. Frontiers of polymer materials :conducting polymers like poly pyrrole, poly thiophene, polyaniline, biomedical polymers, magnetic polymers, non linear optical polymers, liquid crystal polymers

Problems with the polymers: thermoxidative degradation , fire hazards, toxicity, effluent disposal, feedstock scarcity

Low environmental impact polymers: Introduction to low enviromental impact polymers, manufacturing technologies for polymers, economic and market potential for low environmental impact polymers.

Reference books:
2. F W Billmeyer, Textbook of Polymer Science, Wiley Interscience 1994
3. Nick Tucker and Mark Johnson, Rapra technology ltd, UK, Low environmental impact polymers

3. Biomaterials: Structure and function

Introduction to biomaterials, Characterization of biomaterials bulk and surface characterization including degradation, mechanical, electrical, thermal and tribiological properties.

Introduction to hard biomaterials:  
Metals: steel, cobalt-chromium, titanium, new titanium alloys, shape memory alloys, niobium alloys, tantalum alloys  
Ceramics and glasses, alumina, zirconia, diamond like carbon, hydroxyapatite, bioglass, refractory nitrides (TiN), and refractory carbides (TiC) 
Surface modification of biomaterials 
Rapid prototyping of biomaterials
**Introduction to soft biomaterials:** biopolymers (collagen, proteoglycans, cellulose-their structure properties and applications) and synthetic polymers

Polymer synthesis: overview of common polymerization methods

Non-degradable polymer: examples and applications

Degradable polymer: examples and applications

Protein adsorption and biocompatibility, Tissue response to implanted biomaterials

Applications of polymers in tissue engineering and drug delivery.

Reference Books:
1. Sujata V Bhat, Biomaterials 2nd Edition Alpha Science International

4. Semiconductors and Superconductivity

**Semiconductors:** Classification of materials by consideration of their electrical properties. Introduction of band theory, energy band diagrams, band gap.

**Intrinsic and extrinsic semiconductors:** preparation and doping techniques of elemental and compound semiconductors and their characterization, narrow and wide band gap semiconductors, thermoelectric, magnetic and optical properties.

**Different types of semiconductors and their application** in commercial devices Ge, Si, GaAs, InP, PbS. Semiconductor device: metal-semiconductor and semiconductor heterojunctions, physics of bipolar devices, fundamentals of MOS and field effect devices, basics of solar cell.

**Magnetism:** Antiferromagnetism, neutron diffraction, magnetism in Rare earths and antiferromagnetic alloys, helimagnetism, ferrimagnetism, spin glasses, magnetotstriction, domains and magnetization process, single domain particles, coercivity in fine particles

**Superconductivity:** supermagnetism, spintronics, magnetoresistance,

**Type –I superconductivity:** London theory, specific heat and thermal conductivity, intermediate state, measurements of critical currents and magnetic properties, critical state models, Ginzburg-Landau and BCS theory, Josephson effects SQUIDS,

**Type II superconductivity:** pinning of vortices, high temperature, superconductors, flux flow, flux creep, fluctuation effects, levitation and power applications of HTSC.

Reference books:

2. J. Wilson and JFB Hawkes, Optoelectronics – PHI New Delhi

**Lab: Characterisation and testing of materials**

1. Preparation of materials
2. Determination of crystal structure by X-ray diffraction techniques.
3. Distinction between SEM and TEM images by analyzing the micrographs
4. spectrophotometer: band gap determination
5. FTIR

3rd Sem

1. **Solid state phase transformations**

Thermodynamics: equilibrium conditions, statistical thermodynamics of ideal and regular binary solution, energy of mixing and activity, derivation of phase diagrams from the model of solutions, free energy and binary phase diagrams.

Ordering: ordered and disordered transformation, intermediate phases and compounds, superlattices, degree of order, ordered domains and their boundaries, Transformation in steel, affect of alloying elements, various heat treatment processes, transformation in alloy steel, superalloys

Cast iron: heat treatment of cast irons, thermomechanical treatments, non-ferrous alloys, Ti alloys, Al alloys, Cu alloys and their transformation behaviour

Non-metallic systems

Books
1. Rajan and Sharma: Heat treatment, New Delhi
2. I. J. Polmear: light Alloys, Arnold New Delhi
5. V. Raghavan, Phase Transformation, New Delhi

2. **Opto-electronic Materials**

Quantum Mechanics of an electron: time dependent schrodinger equation, time dependent perturbation theory

Quantum mechanics of a photon: Maxwell equations in reciprocal space, fourier transform, quantization of electromagnetic waves, coherent state, black body radiation.

Laser oscillations: Population inversion and optical amplification, laser characteristics, semiconductor lasers: homojunction and heterojunction lasers

Semiconductor Band structure: Crystal structure, effective mass, density of states, carrier statistics in semiconductors

Optical properties of semiconductors: dipolar elements in direct gap semiconductors, optical susceptibility of a semiconductor, absorption and spontaneous emission, bimolecular recombination coefficient, condition for optical amplification in semiconductors

Electronic properties of semiconductors: Boltzmann equation, scattering mechanisms, hot electrons, recombination, transport equation in a semiconductor.

Organic semiconductors: materials for molecular electronics

Semiconductors lasers: homojunction and heterojunction
Materials for optical communication: optical fibers, single and multimode electro-optic effect, liquid crystal displays and displays materials.

Semiconducting glasses: oxide glasses, chalcogenide glasses, insulating glasses, photochromic glasses, fluoride glasses

Electrical behaviour: electronic and ionic conductivity, solid oxide fuel cells, ceramic semiconductors, linear dielectrics, dielectric properties.

Ferroelectric materials, piezoelectrics, ferro-piezoceramics, actuators and electrostrictions, pyroelectrics, electro-optics photorefractives, thin film capacitors.

Ferroic crystals, primary and secondary ferroics, proper ferroics, magnetoferroelectricity

Magnetic ceramics: soft and hard magnetics and their structural considerations.

Reference Books:

4. Optoelectronics: An introduction by Wilson Hawkes
7. Optoelectronics, Emmanuel Rosencher and Broge Vinter, Cambridge University Press

3. Ceramics

Introduction, bonding and structures of ceramics, Types of ceramics

Structural ceramics: Carbides, nitrides, oxides, SiAlON, borides, silicicides, Composites. Synthesis, bonding & structures and applications

Electronic ceramics: Ferro electrics, electrical insulators, smart ceramics, peizo electrics, PLZT sensors, metallised ceramics, gas sensors and superconducting ceramics

Magnetic ceramics: Spinel Ferrites, Hexagonal Ferrites, Garnet. processing and applications.

Special Glasses and Glass Ceramics: High-Purity silica glasses, Laser Glasses, optical glasses, fiber glasses, oxide and non-oxide glasses, oxy-nitride glasses, photosensitive glasses, conducting glasses, glass ceramics, application of glass ceramics, glass for satellite application.

Bioceramics: Introduction, composition, interaction with biological systems, properties, applications, shape memory alloys.

TEXT BOOKS:

1. W. D. Kingery, Introduction to Ceramics, Wiley NY
2. D. W. Richerson, Modern Ceramics Engineering properties, processing and use in design, Marcel Dekker, Inc. N. Y.
4. Nanomaterials

Nanomaterials Foundations: Introduction: Definition, historical perspective, effects of nanoscience and nanotechnology on various fields; Classification of nano-structured materials, top down and bottom up approaches of generation

Classification: Introduction to size dependent phenomenon in nanostructure for various application; Features of nanosystems, characteristic length scales of materials and their properties; Dimensionality of Nanomaterials: fundamental behaviour of 0-D(nanoclusters), 1-D(nanowires), 2-D(thin film multilayers), and 3-D(bulk nanostructures) materials.

Properties: Size and shape dependent properties, color, melting point, magnetism, density of states, conductivity and band gap, metal to insulator transition; Mechanical properties of nano-materials; Magnetic and electronic transport properties of nanostructured materials. Quantum Dots: Electron confinement in various dimensions, single and interacting quantum dots, self organized quantum dots, spectroscopy of quantum dots, nanocrystal superlattices. Introduction to quantum wells wires and dots; Size and dimensionality effects: size effects, conduction electrons and dimensionality, potential wells, partial confinement, properties dependent on density of states, single electron tunneling

Effect of chemistry of nanostructured materials: Modification of nanoparticles, Langmuir Blodgett films, Self assembled surface films, binding of molecules on solid substrate surfaces, molecular nanostructures, strategies of molecular construction, Synthetic supramolecules, Organic Nanoparticles

Synthesis Methods: specific production techniques like chemical vapor deposition, arc ignition etc. Formation of clusters and nanoparticles from supersaturated vapor and selected properties, sputtering and thermal evaporation and laser methods. Synthesis of nanoparticles by chemical routes, Synthesis and characterization on nanoscale, cluster beam evaporation, Processing of semiconducting, metallic and magnetic nanoparticles and their properties and applications

Nanostructured materials: Fullerenes, nanotubes and nano structured carbon coatings, nanostructured materials- nanoparticles, nanomaterials, nanocomposites, nanocoatings and nanocomponent thin film chemical sensors- gas sensors, vapour sensors and biosensors.

Applications: Bio/medical sensing and imaging, micro and nanofluidics, tissue engineering, photonic crystals and optoelectronics. Current and emerging applications for nanomaterials, impact of bio-inspired and bioderived ideas on new and related

Reference books:
1. D. Bimerg, M. Grandmann and N. N. Ledentsov, Quantum Dot Heterostructures, John Wiley and Sons.
2. K. P. Jain, Physics of Semiconductor Nanostructures, Narosa Publication.
4. G. Timp, Nanotechnology by Springer- Verlag 1999
5. A. S. Edlestein and R. C. Cammaratx, Nanomaterials, synthesis, Properties and applications, Inst of Physics Publishing Bristol
7. Owen and Poole, Introduction to Nanotechnology , Wiley
8. A. K. Bandopadhyay,Nano-materials, New Age International
10. Cao, Guozhong, Nanostructures and Nanomaterials - Synthesis, Properties and Applications

4. Minor project (literature survey)

4th Sem : Major project (thesis)

Each student will be required to work on major project approved by department faculty that will span fourth semester during which periodic progress reports will be monitored. At the end of fourth semester the student will submit the thesis based upon his/her project work and project progress will be evaluated by department faculty.