study, and build professional connections with peers, mentors and industry professionals with personality development.

I SEMESTER

MSH 401: MATHEMATICS FOR MATERIALS SCIENCE AND ENGINEERING (4 Credits)

Objectives:

The course is designed to (i) create mathematical problem-solving skills in students for the engineering aspect of materials. (ii) analyze the importance of mathematical tools in the design of materials and technologies of today's world. (iii) solve numerical problems in materials science in competitive examinations.

Expected course outcomes: At the end of the course, (i) students will demonstrate a comprehensive understanding of mathematical tools applied in materials engineering such as heat conduction, vibrations, and stress analysis. (ii) students will be able to apply critical thinking and problem-solving skills in research and professional practice. (iii) students will recognize the mathematical problems, and solve them in competitive exams.

Unit I

Complex Variables: Argand plane-polar representation of complex numbers, DeMoivre's theorem. Analytic functions - Cauchy's theorem, Cauchy's integral formula. Series expansion- Laurent's Theorem. Residue Theorem and evaluation of simple contour integrals. Evaluation of Improper integrals and Integrals involving trigonometric functions by the method of residues - Problems. Group Theory: Basic concepts - multiplication tables - subgroups - direct product. Properties of groups. Representations of finite group - reducible and irreducible representations and example of C_{4V} group. Continuous groups. Related problems. 18 hours

Unit II

Matrices: Matrices as operators. Properties. Symmetric, orthogonal, Hermitian and unitary matrices. Determinant, inverse and rank of a matrix. Eigen values and eigen vectors of a matrix. Similarity, orthogonal, unitary and congruent transformations. Diagonalisation of a real symmetric matrix. Related problems and applications.

Tensors: Definition - Contravariant, Covariant and Mixed tensors. Sum, inner and outer products - Contraction - Quotient law. The line element and the metric tensor. Length of a vector. Raising and lowering of indices. Christoffel symbols and covariant differentiation of tensor. Related problems and applications - Stress and strain tensors. Analysis of strain tensor of an elastic medium - Navier's conditions of equilibrium. Symmetric stress tensor. Generalised Hooke's law - elastic constants of an isotropic homogeneous media - equations of motion - elastic waves –velocity of longitudinal and transverse waves. 18 hours

Unit III

Ordinary differential equations: First-order equations, integrating factor, orthogonal trajectories, Second order linear differential equations with constant coefficients, The Cauchy-Euler equation, Method of undetermined coefficients, variation of parameters, matrix method, Sturm-Liouville problems, trigonometric Fourier series. Partial differential equations: Linear equations, superposition, separation of variable, Second order wave equation, unsteady heat conduction equation, Laplace equation.

Special Functions: Bessel functions of the first kind -derivation of the basic form- Recurrence relations - Fraunhofer diffraction and vibrations of membranes. Legendre and Associated Legendre functions - Recurrence relations and differential equations. Related problems and applications. 18 hours

References:

1. Mathematical Methods for Physicists – G Arfken (Academic Press,1968)
2. Elements of Group Theory for Physicists – A W Joshi (Wiley Eastern,1975)
3. Symmetry Groups and Their Applications – W Miller (Elsevier, 1972)
4. Mathematics of Physics and Chemistry – H Margenau and G M Murphy (Affiliated East West Press, 1966)
5. Matrices and Tensors in Physics – A W Joshi (Wiley Eastern, 1975)
6. Tensor Analysis – I S Sokolnikoff (Wiley, 1974)
7. Mathematical Methods in Physical Sciences – Mary L Boas (Wiley, 2011)
8. Mathematical Methods for Physics and Engineering – K F Riley (Cambridge University Press, 2012)
9. Formal Groups and Applications – Michel Hazewinkel (American Mathematical Society, 2017)

MSH 402 ELEMENTS OF MATERIALS SCIENCE (4 Credits)

Objectives: This course serves as a basic foundation for Materials Science programme. It aims to(i) develop an understanding of how the behaviour/properties of materials are intricately connected to their structure and the type of bonding at the atomic level (ii) correlate the relationship between the atomic structure and crystal energy leading to changes in properties (iii) connect the theories necessary for a deeper understanding of structure-property correlations.

Expected course outcomes: On completing this course, (i) students will be able to analyze the key concepts of structure and bonding in covalent, ionic, metallic, and coordination compounds. (ii) students will relate the fundamentals with the structure property correlations in materials (iii) students acquire the basics required to understand the properties of different class of materials which will be dealt with separately in the forthcoming semester courses (iv) students will be able to apply XRD techniques to identify the crystal structure, lattice parameter and purity of materials using XRD (v) students have opportunities to carry out fundamental research in crystallography/solid state physics.

Unit I

Formation and Structure of Materials: Condensed state of matter-crystalline and amorphous states. Bonding in Materials: Ionic bond - Lattice energy - Madelung constant. Covalent, metallic and molecular bonds. Bond angle, bond length and bond energy – simple problems. Hybridisation - Delocalised chemical bonding. Inert gas crystals - van der Waals' interaction - Lennard Jones' potential. Correlation between bonds and physical properties. Simple crystal structures - Sodium chloride, cesium chloride, diamond and zinc sulphide structures. Close packed structures in two and three dimensions- packing efficiency and density of materials, related problems. 18 hours