Department of Materials Science and Engineering

Syllabus – National level Ph.D. Entrance Examination

The Department of Materials Science and Engineering welcomes applicants from diverse backgrounds to apply for admission to its PhD programs. To screen eligible candidates, a written test will be conducted. As the test is open to candidates from various backgrounds, the syllabus and examination scheme have been designed to accommodate this diversity.

All candidates are required to attempt Module 1, while they have the flexibility to choose any one section from Module 2. The exam will last for one hour and will consist of 15 questions from Module 1 and 15 questions from Module 2. Each question carries one mark, with a total of 30 marks available.

MODULE 1 (Mandatory for all candidates)

Basic materials science: Classification of materials: metals, ceramics, polymers, and composites. Nature of bonding, fundamentals of crystallography, symmetry operations, crystal systems, Bravais lattices, unit cells, primitive cells, crystallographic planes, and directions; Structures of metals, ceramics, polymers, amorphous materials, and glasses.

Suggested Text books / Reference books:

1. Callister, W. D. Jr., & Rethwisch, D. G. (2018). Materials Science and Engineering: An Introduction (10th ed.). Wiley.
2. Raghavan, V. (2015). Materials Science and Engineering: A First Course (6th ed.). PHI Learning.
3. Shackelford, J. F. (2021). Introduction to Materials Science for Engineers (9th ed.). Pearson Education..

Quantitative and logical reasoning: Arithmetic, Number Systems, Time, Speed, and Distance, Time and Work, Algebra, Basic Algebraic Identities, Linear Equations, Quadratic Equations, Polynomials, Trigonometric Ratios, Trigonometric Identities, Heights and Distances, Data Interpretation, Probability, Permutation and Combination

English language comprehension: Reading Comprehension, Passage Selection, Drawing Inferences, Vocabulary, Synonyms and Antonyms, Word Meanings,Contextual Usage, Analogies, Grammar, Parts of Speech, Sentence Structure, Tenses, Subject-Verb Agreement, Verbal Reasoning, Logical Deductions, Statement and Conclusion. Statement and Assumption, Statement and Inference, Passage Conclusion, Understanding Context, Filling in the Blanks, Error Spotting, Grammar Errors, Spelling Mistakes, Sentence Completion, Sentence Improvement, Sentence Reconstruction

MODULE 2 (Choose any one section)

Section 1: Physical and Mechanical Metallurgy

Defects in crystalline materials. Alloying, Phase diagrams, Phase transformation, TTT diagrams, Non equilibrium cooling, precipitation hardening, Diffusion in solids, Heat treatment . Concept of stress and strain, mechanical properties of materials, concept of dislocations, dislocation theory, Plastic deformation, slip, twinning, creep, fatigue, fracture, strengthening mechanisms, elements of theory of plasticity, metal forming processes.

Section 2: Physics of Materials

Physical, Mechanical, Chemical, Electrical, Thermal, Optical, Magnetic properties of materials, Postulates of quantum mechanics; Uncertainty principle; Schrodinger equation, Electron motion in a periodic potential, band theory of solids: metals, insulators and semiconductors, Charge Carriers, Semiconductor devices and device structures (diodes, junctions, transistors, field effect devices, homo and heterojunction devices), Device characteristics, Hall effect, Optoelectronic devices (solar cells, photo-detectors, LEDs, LASERS), Phonons, Free electron theory, Thermoelectric power, Superconductivity: type-I and type-II superconductors, Josephson junctions and tunnelling, Plasmons, Excitons.

Section 3: Chemistry of Materials

Classes of materials- inorganic and organic materials, surfaces, interfaces, Nanomaterials, thin films, and multilayers, porous materials, Covalent organic frameworks, porous organic polymers and related organic porous materials, soft materials- effects of synthesis on the structure and properties of various materials. Chemical and catalytic aspects of materials, catalytic action, electrocatalysts, and photocatalytic materials.

Section 4: Fluid mechanics and heat transfer

Fluid mechanics: Properties of fluids: density, pressure, viscosity, surface tension, capillarity, vapour pressure; Buoyancy, Bernoulli's equation; laminar and turbulent flows, entry length, Hagen-Poiseuille equation; Darcy-Weisbach equation; energy losses in pipes; Fluid pressure and velocity measurement,

Heat Transfer: Conduction: Generalized differential energy equations of heat conduction; types of boundary conditions; lumped heat capacity systems; Thermal conductivity, Thermal contact resistance. Convection: Newtons law of cooling; forced, mixed and natural convection heat transfer; hydraulic and thermal boundary layer, heat exchangers, parallel and counter flow heat exchangers, effectiveness, boiling and condensation

Section 5: Materials Characterization

X-ray diffraction, bragg's law, structure factor, lattice strain, quantitative analysis using XRD; spectroscopic techniques such as UV-Vis, IR and Raman; optical microscopy: resolution and limit of resolution, different types of optical microscopes and operation modes. Electron microscopy,basic construction and working principle of SEM, beam specimen interaction, imaging modes, sample preparation for SEM. TEM : Basic construction and working principle of TEM. Imagine and diffraction modes in TEM, basics of electron diffraction, Energy dispersive spectroscopy in SEM and TEM, sample preparation for TEM. Tensile test, hardness measurement. Electrical conductivity, carrier mobility and concentrations. Thermal analysis techniques TGA, DSC etc.

Section 6: Biomaterials

Different class of materials used in medicine – polymers, metals, ceramics, Biomaterials- Bioinert, Bioactive and Bioresorbable materials; Implants, dental materials, stents, shape memory alloys, drug releasing hydrogels and biomimetic system. Testing of biomaterials: In vitro and In vivo studies, Simulated body fluids, MTT Assay, Time kill Assay, Cell culture studies, Drug delivery systems, Anti
bacterial and Anti-Fungal systems. Tests for biocompatibility. Bone fillers and Dental cements: zinc phosphate, zinc polycarboxylate, glass ionomer, resin-modified glass ionomers (RMGIs), and resin cements, etc. Testing of cement and fillers. Grafts: Autograft, Isograft, Allograft, Xenograft etc. Working principles of major diagnostic instruments: X-ray, MRI, CT scans, USG etc, Biofouling, Biological environment and host response – Inflammation, wound healing, and foreign body response, Degradation of implanted materials: polymers, metals, ceramics, biocompatibility- methods for improvement, Biosensors.

Section 7: Computational Methods in Materials Science

Computer simulations as a tool for materials science: Need and Prospects, Length and time scales of multiscale modeling. Basics of statistical mechanics: Probability, Entropy and temperature, Boltzmann distribution, Thermodynamic ensembles, ergodicity.

Ab initio methods: Schrodinger equation, Electronic states of many particle systems. Introduction to first principles energy methods: The Hartree-Fock approximation, Density functional theory

Atomistic Simulation Techniques: Molecular Dynamics (MD) - Introduction, inter-atomic potential functions, Lennard-Jones potential, equilibration and property evaluation