I-PHD NANOTECHNOLOGY ENTRANCE SYLLABUS (2021-22)

NOTE: The syllabus comprises of three sections I, II and III. **Section I is compulsory** while as students have an option to choose between **Section II and Section III**. Only two sections have to be attempted in the test.

SECTION-I

Unit-1

Nanoscience and Nanotechnology: Background history, introduction and definition with suitable examples. Difference between nanoscience and nanotechnology and its interdisciplinary nature. Tools of Nano (evolution of nanotechnology). Importance and emergence of nanotechnology in various sectors. Grand challenges facing nanoscience and nanotechnology. Classification of nanomaterials: zero-dimensional (clusters), one-dimensional (nanowires), two-dimensional (thin films and graphene) and hierarchical nanomaterials.

Unit-2

Materials and their types. Crystalline solids: close packed structures, unit cells and their types, two- and three-dimensional Bravais lattices, crystal systems, crystal planes and Miller indices, symmetry elements in crystals, point groups and space groups.
Nanosize effects - surface to volume ratio (surface effects) and quantum confinement effect in quantum dots. Surface plasmon resonance and its dependence on various factors. Surface energy of nanomaterials. Variation in physical properties of nanomaterials in comparison to bulk materials: Lattice constants and melting point and electrical conductivity.

Unit-3

Basic synthetic strategies for nanomaterial synthesis: Top down and bottom-up approaches. Laser ablation, Ball milling, Lithographic techniques, Pyrolysis and other methods, Molecular beam epitaxy, Chemical vapor deposition method. Chemical methods - Metal nanocrystals by reduction, Solvothermal/hydrothermal route, Sonochemical and Microwave assisted synthesis, Micelles and microemulsions. Nanofibers synthesis by Electrospinning method- various parameters influencing nanofiber morphology, porosity and other characteristics.

Unit-4

Electromagnetic radiation characteristics, quantization of energy, regions of EM spectrum. Width and intensity of spectral transitions. Electronic absorption spectroscopy, types of

transitions and selection rules, Franck-Condon principle. Radiative energy-transfer processes and Jablonski diagram. Infrared spectroscopy - The functional group and fingerprint regions, Characteristic IR absorption bands, Intensity and position of absorption bands. Interpretation of an IR spectrum (examples).

Unit-5

Electron probe characterization methods. Optics and resolution, Electron interaction with matter. Electron Microscopy (Scanning Electron Microscopy and Transmission Electron Microscopy) - operational principle and applications. Scanning probe microscopy (AFM, STM) - operational principle and applications, Other important electron probe methods: Auger electron spectroscopy, Low energy electron spectroscopy (LEED) and Energy electron loss spectroscopy (EELS).

Unit-6

XRD – operational principle and applications. Nano Perspective - Peak broadening and crystallite size- The Scherrer equation. X-ray photoelectron spectroscopy (XPS). Surface area and porosity, Particle size determination by light scattering and surface charge on nanoparticles (Zeta potential). Thermal analysis methods: Principle and Instrumentation of Thermogravimetry; Differential Thermal Analysis and Differential scanning calorimetry.

Unit-7

Dia, para and ferromagnetic materials, Origin of magnetism – various theories, temperature dependence, domain structure ferromagnetic domains, antiferromagnetism, magnetic hysteresis and coercive force. Magnetization and nanostructures: Superparamagnetic particles-susceptibility and related phenomena in superparamagnets- Physical properties of magnetic nanostructures-exchange coupled magnetic nanomaterials-spin–polarized tunneling- magnetoresistivity, Data storage applications of magnetic nanoparticles, spintronic devices

Unit-8

Nanothermodynamics - Thermodynamics the nano perspective – Background- application of classical thermodynamics to nanomaterials - small system thermodynamics. Modern nanothermodynamics - Nonextensivity and nonintensivity - nanothermodynamics of a single molecule.

Carbon based nanomaterials - Carbon Nanotube (CNT), Graphene, Carbon Nanofoam and Buckminster Fullerenes Structure and mechanical properties of carbon nanotubes and its

Composites- nanomechanical measurement techniques. Micro and Meso and Nanoporous materials

SECTION-II

Unit-1

Bonding in crystal - cohesive energy, Defects in crystals: Point defects (Frenkel & Schottky), line defects (slip, plastic deformation, edge dislocation, screw dislocation, Burger's vector, concentration of line defects, estimation of dislocation density), dislocation multiplication (dislocation reaction), surface (Planar) defects, grain boundaries and stacking faults.

Unit-2

Boltzmann's transport equation, electrical and thermal conductivities of solid, Wiedemann-Franz law, Free electron theory of metals; Electrons in periodic lattice: Bloch theorem, the Kronnig Penny model, band theory, classification of solids on the basis of band theory.
Semiconductors – carrier concentration and fermi level and extrinsic and intrinsic, Transport phenomenon in semiconductor - Hall Effect.

Unit-3

Lattice vibration and thermal properties: Einstein and Debye models; continuous solid; linear lattice; acoustic and optical modes; dispersion relation; attenuation; density of states; quantization of lattice vibrations, the concept of phonons and quantization; phonon momentum, Inelastic scattering of neutrons by phonons, Surface vibrations. Brillouin zones; thermal conductivity of solids. Thermal expansion.

Unit-4

Scattering, transmission and absorption in solid. Polarization, dielectric constants, Clausius-Mossotti equation, sources of polarization, frequency dependence of dielectric constants, ferroelectrics and piezo-electrics.
Superconductivity and critical temperature, type-I and type II superconductors, Meissner effect, Josephson junction, Cooper pairs, BCS theory

Unit-5

Electronic Structure of ID Systems, ID Sub-bands, Spectroscopy of Van-Hove Singularities, ID Metals-Coulomb Interactions and Lattice Couplings, Electrical Transport in ID, Conductance

Quantization and the Landauer formula, two barriers in series-resonant Tunneling, Incoherent Addition and Ohm's law, Voltage Probes and the Buttiker-Landauer formalism.

Unit-6

Quantization in Semiconductor Nanocrystals, Metallic Dots, Discrete Charge States, Coulomb Oscillations, Spin, Mott insulators, and the Kondo Effect.
Applications of direct band gap semiconductor nanoparticles, LED and solar cells, electroluminescence, Mn-Zn-Se phosphors, light emission from indirect semiconductors - Si nanodots. Recent advances in solar cell technology - Perovskite and dye sensitized solar cells.

Unit-7

Semiconductor bandgap Engineering, Junction (PN, MS) diode analysis and its applications, Transistors (BT, MESFET, MOSFET) and its applications, CMOS technology with design examples.
Fundamentals of sensors, biosensor, micro fluids, MEMS and NEMS. Packaging and characterization of sensors. Nanobiosensor- CNT biosensor, Nanowire Biosensors

SECTION-III

Unit-1

Biomolecules: Structure, Classification, and biological importance of Carbohydrates, Lipids, Proteins, Nucleic Acids. Enzyme Classification and Kinetics, Regulation of Enzymatic Activity, Enzyme Inhibition, Coenzymes, Denaturation and Annealing of DNA, Cot Curve; **Metabolism:** Glycolysis and TCA cycle, Glycogen breakdown and synthesis, Gluconeogenesis, Regulation and Co-ordinated control**,** Oxidation of lipids α, β, ω, oxidation, Biosynthesis of saturated and unsaturated fatty acids, Biosynthesis of Triacylglycerols, Formation and utilization of Ketone bodies**,** Biosynthesis of Purines and Pyrimidines, Inborn Errors of Nucleic acid Metabolism, Metabolic disorders-Diabetes.

Unit-2

Molecular Biology: DNA as a genetic material, Structure and Functions of various types of RNA General features of DNA replication: Initiation, Elongation and Termination of Replication, Transcription in prokaryotes and eukaryotes, Translation: Protein synthesis and genetic code, Positive and negative regulation of translation, Post Translational Modifications.

Unit-3

Cell Biology: Structure and function of cells in prokaryotes and eukaryotes; Structure and organization of Membrane - Model membranes, Glyco conjugates and proteins in membrane systems; Response to stress - active and passive, transport channels and pumps, neuromuscular junction. Extra cellular matrix – cell to cell and cell matrix adhesion – selectins, Integrins, cadherins, gap junctions. Mechanism of cell division: regulation of cell cycle; factors and genes regulating cell cycle. **Physiology**: Blood flow and circulation, Transport and exchange of oxygen and carbon dioxide in body.

Unit-4

Immunology & Therapeutics: Cells of Immune system, Natural Molecular Recognition, Innate Immune System, Adaptive Immune System, Cytokines, Antigens, MHC restriction, Cell mediated cytotoxicity: Mechanism of T cells and NK cell mediated lysis, ADCC and macrophage mediated cytotoxicity. Immune response against parasitic and viral infections; Hybridoma Technology for monoclonal antibodies- Application of Monoclonal antibodies as therapeutics for various diseases; Tumor immunology, Immunotherapy for Cancers

Unit-5

Cell Signalling: The basic elements of cell signaling, Endocrine and Neurocrine signal modulators and their receptors. Functions of G-protein- coupled receptors and second messengers. Protein phosphorylation and its role in signal transduction. Cytokine Receptors: Role of calcium and NO as intracellular messengers. Detailed mechanism of signaling in the following pathways: GPCR pathway, RAS, MAPK pathway, PI3K/mTOR Kinase Pathway, Neurotransmission.

Unit-6

Cancer Biology: The nature of cancer, causes of cancer, Viral and cellular oncogenes, Tumour suppressor genes, Properties of cancer cell, Hallmarks of cancer, cell immortalization and tumorigenesis, Insensitivity to antigrowth signals, Evading Apoptosis (Anoikis), Angiogenesis, Tissue invasion and metastasis, Conventional chemotherapy drugs their mechanism and limitations.

Unit-7

Nanomedicine: Nanoscale in Biological Systems, Applications of Nanoscience in biological systems- drug targeting & drug delivery, various nanoscale materials in drug delivery: PLGA, PLA, chitosan, Liposomes, Polymers, and Dendrimers. Biological barriers encountered by

biodegradable nanoparticles-Viral Vectors, Physicochemical approaches for targeting drug delivery- Magnetic thermal and pH assisted drug delivery. Affinity based (Synaphic) delivery of nano-composites; Receptor based delivery, Peptides as targeting agents, EPR effect for cancer therapeutics. Nano-sensors as diagnostic tool in bio-medical applications.