Dr. Babasaheb Ambedkar Marathwada University
Aurangabad 431004, Maharashtra, India

Department of Nanotechnology

Curriculam
for
Ph.D. Entrance Test – 2016 (PET)

{ As per UGC – 2016 and Dr. Babasaheb Ambedkar Marathwada University rules }

Section A
Research Methodology

Unit I: Research Fundamentals:

Introduction: Definition, objectives of the research, characteristics of the research, what makes people to do research, importance of research

Research categories: Basic research, Applied research-problem solving research and problem oriented research, Some other types of research-evaluation research; performance monitoring research; total quality management (TQM), Types of research, Features of good research study, Entering into the research, Qualities of a good researcher, The research process: Identifying the problem, developing research strategy, collection of data, analysis of collected data, preparation of research report, organization of research report

Unit II: Defining Research Problems and Hypothesis Formulation:

Defining the research problem: Identification of research problems, selection of research problem, facts one should know regarding selection of research problem, the process of research problem definition, some facts involved in defining research problem, Formulation of the problems: steps involved in defining a problem, formulation of the problems, Formulation of hypothesis: Concept of hypothesis, hypothesis testing , Developing the research plan: implementation, interpreting and reporting the findings, Importance of hypothesis of in decision making.

Unit III: Methods and Techniques of Data Collection:

Types of data: primary and secondary, distinction between primary data and secondary data, Data collection procedure for primary data: planning the study, modes of primary data collections, primary data observation process, primary data experimentation methods, primary data questionaries' techniques, limitations of primary data collections, different types of study through primary data; Methods for secondary data collections: secondary data may either be published data or unpublished data, sources of unpublished data, secondary data- internal, secondary data-external.

Unit IV: Research Report and Proposal Writing:

Introduction, research proposal writing: costing, the research proposal, rationale for the study, research objectives, research methodology, target respondents, research Centres, sample size and sample composition, sampling procedures, research project execution, research units; An insight into research report and proposal, research project synopsis, research report writing : types of research reports, guidelines for writing reports; Steps in writing report, report presentation, typing the report, documentation and bibliography, formatting guidelines for writing a good research report / research paper.

References:

1. Research Methodology by Dr. S. L. Gupta, Hitesh Gupta (International Book House Pvt Ltd (2013)
2. Basic Research Methods-Gerard Guthrie
3. Principles of Research Methodology- Phyllis G. Supino, Jeffrey S. Borer
4. Research Methodology-methods and techniques- C. R. Kothari
5. Research Design Qualitative, Quantitative. and Mixed Methods Approaches- John W. Creswell
6. Research Methodology -A Step-by-Step Guide for Beginners- Ranjit Kumar
7. Scientific Writing and Communication- Angellka Hofmann
8. Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded- Joshua Schimel
9. Handbook of Scientific Proposal Writing- A.YavuzOruc

Section B

Unit I Quantum Physics- (Quantum mechanics for Nano particles)

Introduction to Quantum mechanics, Nanostructural Materials and Low dimensional structures.

Basic principles of Quantum mechanics (why and how classical mechanics fails), probability amplitude, wave functions, eigen states and eigen values, Quantum wells, Quantum wires, Quantum dots, Nano clusters and Nano crystals.

Nano Mechanics

Nano scale mechanical properties of solid surfaces and thin films, scale effects in mechanical properties, mechanics of Biological Nanotechnology.

Quantum mathematical concepts for Nano particles.

Theory of linear differential, non linear differential, Partial Differential Equations and Ordinary Differential Equations, Basic concepts of statistics (M-B, B-E, and F-D statistics), data collection and measurement, Probability, Probability distributions and probability densities, Functions of random variables, Graphical and tabular displays of data, Numerical summaries of data, Partition function and its application for electrical, optical, magnetic and low temperature phenomena .

Properties of Quantum nano material

Structural, optical, magnetic and electronic properties of nanocrystallites, Vibrational properties of nanocrystallites, Quantum mechanical properties of nano structural materials.

Quantum mechanical application of Nanotechnology

Quantum well and quantum dot lasers, ultra-fast switching devices, nano magnets for sensors and high density data storage, photonic integrated circuits, long wave length detectors, carbon nanotube, luminescence from porous silicon, spin-tronic devices.

Introduction to Quantum Mechanics: Failures of Classical Mechanics; Brief discussion of general ideas such as "Wave particle duality", uncertainty principle, superposition principle etc.; solutions to Schrödinger Equation for 1-D and 3-D square wells and potential barriers, H-atom.

Matrix Mechanics: Operators, change of basis, Eigen values and Eigen vectors; Simultaneous Eigenvectors, Harmonic oscillator in matrix mechanics; Exchange operator and identical particles.

Angular momentum: Introduction to angular momentum operators; Eigen values and eigenvectors of L^2, L_2 Spin and J^2 and J_2

Approximation Methods: Non-Degenerate and degenerate perturbations theory and applications to anharmonic oscillator; Variational method with application to the ground states of harmonic oscillator and hydrogen atom; General expression for the probability of transition from one state to another, constant and harmonic perturbations.

Scattering Theory: Scattering Cross-section and scattering amplitude, partial wave analysis, Born approximation and its application to simple potentials. *Theory of Ensembles:* The microcanonical ensemble theory and its application to ideal gas of monatomic particles; The canonical ensemble and its thermodynamics; Partition function, energy fluctuations, equipartition; A system of harmonic oscillators as canonical ensemble; The grand canonical ensemble and significance of statistical quantities.

Quantum Statistics: Quantum states and phase space, the density matrix, few examples; An ideal gas in quantum mechanical ensembles; statistics of occupation numbers. Basic concepts and thermodynamic behavior of an ideal Bose gas, Bose-Einstein condensation; Discussion of a gas of phonons (The Debye field); Thermodynamics of an ideal fermi gas, heat capacity of a free-electron gas at low temperatures; Pauli paramagnetism.

Unit II Solid State-(Solid State and Nano Material Science)

Introduction: Classification of materials: crystalline, non-crystalline, nano-phase solid, Lattice translation vectors and lattices, basis crystal structure, Primitive and non-primitive cell fundamental types of lattices, characteristics of cubic lattices closed packed structures, Miller indices, symmetry elements, point groups and space groups, examples of simple crystal structures.

Zero-Dimensional Nanostructures: Nanoparticals:

Introduction , Nanoparticles through Homogeneous Nucleation, Fundamentals of Synthesis of semiconductor nanoparticles, Synthesis of oxide,nanoparticles, Vapor phase reactions, Solid state phase segregation, Heterogeneous Nucleation and Growth, i.Fundamentals of heterogeneous nucleation, ii.Synthesis of nanoparticles, Kinetically Confined Synthesis of Nanoparticles, i. Synthesis inside micelles or using microemulsions, ii. Aerosol synthesis, iii. Growth homogeneous nucleation, ii.Subsequent growth of nuclei, iii.Synthesis of metallic nanoparticles,iv termination, iv. Spray pyrolysis, v. Template-based synthesis, Epitaxial Core-Shell Nanoparticles.

One-Dimensional Nanostructures: Nanorods and Nanowires :

Introduction, Spontaneous Growth, Evaporation (or dissolution) condensation, Vapor (or solution or solid)–liquid–solid growth, Stress-induced recrystallization, Template-Based Synthesis, Electrochemical deposition, Electrophoretic deposition, Template filling, Electrospinning, Lithography

Two-Dimensional Nanostructures: Thin Film:

Introduction, Fundamentals of Film Growth, Vacuum Science, Physical Vapor Deposition (PVD) i.Evaporation, ii. Molecular beam epitaxy, iii. Sputtering; Chemical Vapor Deposition (CVD), i. Types of chemical reactions, ii. Reaction kinetics, iii. Transport phenomena, iv. CVD methods, v. Diamond films by CVD; Atomic Layer Deposition (ALD), Superlattices, Self-Assembly, Langmuir-Blodgett Films, Electrochemical Deposition, Sol-Gel Films, Solution growth, SILAR films.

Special Nanomaterials and applications:

Introduction; Carbon Fullerenes and Nanotubes: Carbon fullerenes, Fullerene- derived crystals, Carbon nanotubes; Micro and Mesoporous Materials: Ordered mesoporous materials, Random mesoporous materials, Crystalline porous materials (zeolites); Core-Shell Structures: Metal-oxide structures, Metal-polymer structures, Oxide-polymer structures; Organic-Inorganic Hybrids: Class I hybrids, Class II hybrids; Intercalation Compounds; Nanocomposites and Nanograined Materials.

Molecular Electronics and Nanoelectronics; Nanobots; Biological Applications of Nanoparticles; Catalysis of Gold Nanocrystals; Bandgap Engineered Quantum Devices: Quantum well devices, Quantum dot devices; Nanomechanics; Carbon Nanotube Emitters; Photoelectrochemical Cells; Photonic Crystals and Plasmon Waveguides.

Semiconductor Electronics:

Physics of Semiconductor materials, Drift velocity, Mobility, Scattering, Diffusion current, Band model.

Metal Semiconductor Contacts:

Metal-Semiconductor system, (V-I) and (C-V) equations for a Shottky – Barrier – Diode, Diode construction, Device analysis using surface – states, applications as mixer and detection in microwave region, Ohmic contacts, Surface effects.

PN Junctions:

Step junction, linearly graded junction, (V-I) and (C-V) characteristics, Junction Breakdown, Tunneling effect, avalanche multiplication, transient behaviour and noise. Use of Junction diode as a rectifier, Voltage regulator, resister varistor and fast recovery diode.

Bipolar Junction Transistors:
Transistor action, Current- Voltage equation, Output Characteristics, breakdown voltage, Ebers-Moll and Gummel-Poon Model, Early effect, Charge control model, small-signal transistor model, Simulation model.

Metal-oxide-silicon System:
MOS structure, Energy Band Diagrams, Interface Charges, Surface effects, MOS Capacitors.

MOS Transistors:
Basic Theory, structure and operation, MOSFET Parameters, Threshold voltage and its control, Geometric effects on threshold, Ion- Implanted MOSFETs, Complementary MOSFET, Sub-threshold Conduction, Velocity saturation, hot carriers, small geometry considerations.

Unit III Chemistry-(Nanochemistry and naostructured systems)

Introduction of Bonding in solid Material
Homonuclear and heteronuclear diatomic molecules - orbital diagrams, bond order, bond energy and magnetic properties. Ionic/covalent character/dipole moments - HX type molecules. Main group elements - shapes and structures using VSEPR. Bonding in transition metal complexes - coordination compounds, introduction, crystal field theory. Cubic, Octahedral, tetrahedral and distorted square planar shapes from octahedral complexes - stabilization energies and magnetic properties.

Chemical Bonds and phase studies in solid chemical materials
Chemical bonds, ionic, metallic, covalent and shearing bonds in solid materials. Different phases studies of conductor, semiconductor, insulator and polymers in nano phase, phase equilibrium and phase transitions, chemical reaction and their mechanism, engineering of chemical reactions for nano particle growth, thermodynamics and kinetic considerations for nanoparticles, rate limiting factors

Synthesis and types of nano particles
Nanocontainers, Nanoshells, Nanohorns, Nanowires, Nanosprings, Nanorods, Nanofilters, Nanopens, Nanopencils, Nanopipettes, Nanopens, Nanoplotter, Nanobalance, Nanobeads, Nanoguitar:

Characterization and Properties of Nanomaterials
Introduction, Structural Characterization, X-ray diffraction (XRD), Small angle X-ray scattering (SAXS), Scanning electron, microscopy(SEM), Transmission electron microscopy (TEM), Scanning probe microscopy (SPM) Gas adsorption. Chemical Characterization, Optical spectroscopy, Electron spectroscopy, Ionic spectroscopy, Physical Properties: Thermal stability and lattice constant, Mechanical properties, Optical properties, Electrical conductivity, Ferroelectrics and dielectrics, Superparamagnetism, Emission spectroscopy, luminescence spectroscopy.

Application of nano chemistry
Semiconductor and Microelectronics including MEMS, Optical Magnetic including memory, read-write, flash, bubble memories etc. Mechanical including Nanocomposites, thermal barriers etc.Biomedical including Pharmacology, Virology etc.

Chemical Synthesis of Nanomaterials- Different types and processes for synthesis of nanomaterials using wet chemical approaches. Fabricating nanomaterials with different morphology intended for specific applications.

Fundamentals of Instrumental Analytical Techniques- UV-vis spectroscopy (liquid and solid state), Infrared spectroscopy, Raman spectroscopy, Mass spectrometry, Thermal Analysis Methods etc

Molecular Nanotechnology- Low Energy Electron Diffraction (LEED), Scanning Probe Microscopy-principle of operation, instrumentation and probes, Low temperature Scanning

Probe Microscopy, Auger, SEM, TEM, XRD (Powder/Single crystal), Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy (STM), EDAX, XRF, ESCA, Optical microscope, UPS (UV Photo electron spectroscopy).

Experiments in Ultrathin films: Ellipsometry, Nanotweezers, Nanodots, self assembly and Nanolithography. Physical methods such as various forms of spectroscopy for the analysis of biological systems- Force spectroscopy, XPS, X-ray Photon Spectroscopy, EDS, Electron Dispersion Spectroscopy etc.

Unit IV Biosciences- (Nano Biosciences, Biomedical & Biotechnology)

Introdcution: Cellular Structure and Function, Inheritance, Molecular Biology and Biotechnology, Microbial and Plant Bioscience, Animal Bioscience and Statistics for Bioscience.

Nutrition and Metabolism, Cell Biology, Molecular Biology and Genetics, Introductory Microbiology and Human Physiology.

Advanced study: Plant Biology and Ecology, Biochemistry in Health and Disease, Molecular and Cellular Biology and Microbiology. Applications in Biomedical and Environmental Biotechnology.

Key issue in medical sciences: Classes in Genes and Cancer, Glycobiology, Pharmacokinetics, Molecular Neuroscience, Oxidative Stress, Advanced Aspects of Molecular, Cardiovascular, Neuropharmacology and further study of major disease states.

Medical Biochemistry: Molecular Genetics, Proteins and Enzymes, Nano Pharmacology of Synaptic Transmission, Drug Receptor Interactions, Methods in Biosciences and Pharmacology, Preparation of nano-particulates, Study of nano-particulate surface stabilizers, Applications and benefits of nano-particulate drugs.

Biotechnology: An overview-definition, scope and importance, Steps in Gene Cloning.

Cell Structure and Physiology: Cell: structure, function and types, cell multiplication; Biomolecules- Carbohydrates, Proteins, Lipids, Nucleic acids; Cellular metabolism: energy yielding and energy requires pathways, Transport of Nutrients across cell membrane.

Microbial Biotechnology: Bacterial Division, Growth and Nutrition, A brief account of microbes in industry and agriculture.

Plant Biotechnology: Gene transfer methods in plants, Transgenic plants (A brief introduction), Chloroplast and mitochondria engineering. *Animal Biotechnology***:** Transfection techniques and transgenic animals. Cloning of animals, Hybridoma technology and Monoclonal antibodies.

Medical and Environmental Biotechnology: *Medical Biotechnology***:** Biotechnology in medicine, Vaccines, Diagnostic, Forensic, Gene therapy. *Environmental Biotechnology***:** (A brief account) Role of biotechnology in pollution control, Sewage treatment, Energy management, Bioremediation, Restoration of degraded lands and Conservation of biodiversity.

Sequence Databases EMBL, NCBI, DDBJ, Protein structural Databank, Sequence Analysis of Proteins & Nucleic acids.

Bioinformatics: (A brief account) Importance, Scope of Bioinformatics, Use of Databases in Biology.

Unit V Applications of Nanotechnology in various fields

Introduction: An introduction to energy sources, present energy consumption and need, world energy futures, energy sources and their availability commercial or conventional energy sources and new energy technologies. Renewable energy sources and prospects.

Solar Energy: Solar Radiation and its measurements, Solar Radiation at the earth surface, Solar Radiation Geometry, Measurements, data, and average solar radiation. Solar energy

collectors, transmissive flat-plate collectors, concentrating collectors: focusing type and principle of the conversion of solar radiation into heat. Advantages and disadvantages of concentrating collectors over flat-plate and progress in the field. Solar energy storage, solar energy storage system, solar pond, principle of operation and description of non convective solar pond, extraction of thermal energy and application of solar ponds.

Application of solar energy, Solar water heating, Space heating/cooling (solar heating/cooling of buildings), Solar thermal electric conversion, Solar electric power generation: solar photo – voltaic, Agriculture and industrial process, Solar distillation, pumping, furnace, cooking, green houses and production of hydrogen.

Biosensors - Present state of art and future potential: Devices for testing in the Doctor's Office, e.g. of blood and urine samples, for Home Monitoring; for Ambulance Monitoring; for Bedside Monitoring. Blocks to a full present implementation of such sensors: Technical Problems, Business constraints, Regulatory constraints. The potential of nanotechnology to remove these blocks.

Imaging and targetted drug delivery This section will address the novel nanoscale imaging and drug delivery agents now arising at the research level. Recent trend and progress in MRI contrast agents. Recent trend and progress in bioimaging. Recent trend in diagnosis and treatment of diseases.

Unit VI Advances in Nanotechnology- (Carbon Nanotubes and its Technological Applications)

Carbon Nanotubes (CNTs)-Introduction to CNTs and significance in R&D, different carbonaceous material, difference in carbon and CNTs. Synthesis (types), processing, properties and characterization. Chemical Vapour Deposition of CNTs using structural nanoparticle catalysts and its role in single walled carbon nanotubes (SWNTs) by chemical vapour deposition (CVD).

Charge transport in CNT Films and Fibers, Electrical and magneto transport properties of various types of carbon nanotubes arrays. Doped CNTs and the effect of doping (Aluminum, Boron, Nitrogen and Phosphorous on the models of CNTs. Characteristic properties of doped CNTs. Fundamentals of Carbon Nanotube Transistors (carbon nanotube field effect transistors -CNT-FETs). The I-V characteristics of CNT-FETs. Compact models for carbon nanotube transistors and interconnects for nanoelectronics. Interconnect challenges.

Affinity of CNT for metal - Its importance to application: Molecular dynamics approach, Carbon nanotube field emitters, CNTs as sensor material and their sensing mechanisms. Gas sensors based on decorated carbon nanotubes, Applications in Physical Sensors and Actuators, study of CNT-FETs for NEMS, CNT-FET nanoelectronics can achieve significantly greater performance than Silicon technology.

Solid phase (micro) extraction tools based on carbon nanostructures (nanotubes, fullerenes, and nanocones) for analytical methods, sorbent for analysis of environmental pollutants, liquid crystal dispersions of CNTs: dielectric, electro-optical and structural peculiarities, functionalization of carbon nanotubes with luminescent silicon nanocrystals, functionaliation of CNTs (fluorinated single-walled (F-SWCNTs) and multiwalled (F-MWCNTs), characteriation and electronic structure. Nucleic acid interaction and interfaces with single-walled CNTs (biosystems), DNA-protein wrapped CNTs from Synthesis to Application, Microwave Dielectric Properties of Carbon Nanotube Composites. The environmental effects on the optical properties of SWNTs and MWNTs. Hydrogen storage by carbon materials, CNTs as a new type of electrode materials for Supercapacitors, CNTs Membrane Solar Sails for Extremely Fast Space Flight. Carbon Nanotube-Nanoparticle Hybrid Structures, Superconductivity in carbon nanotubes.

Nanotoxicology: Nanotechnology is poised to make the nano-revolution a reality in the manufacturing sector and on the verge of commercialization. From these perspectives,

exploring the developments in nanotechnology are transforming areas as diverse as medicine, advanced materials, energy, electronics and agriculture. Nanotechnology: Health and Environmental Risks introduces risk analysis as a tool for responsible environmental decision making in nanotechnology development and provides examples of past, present, and future technologies that demonstrate the need for and benefits of evaluating the risks of nanotechnology. Risks, Regulation and Management strategies.