Faculty of Science

NORTH MAHARASHTRA UNIVERSITY, JALGAON.

Syllabus For

Master of Science
(M. Sc.)

in

Nano Science and Technology
(w.e.f. July 2013)

NORTH MAHARASHTRA UNIVERSITY, JALGAON

Syllabus – M. Sc. Programme- Nano Science and Technology

Eligibility Criteria

The eligibility condition for admission to M. Sc. Nanoscience and Technology course is any Bachelor's Degree in Science (B.Sc.). The admission process includes selection through nationwide entrance test.

PART-I (Semester I and II)

Semester I

Paper I: Introduction to Nanoscience and Nanotechnology 100 marks
Paper II: Chemistry of Materials 100 marks
Paper III: Physics of Materials 100 marks
Paper IV: Cell Biology and Biochemistry 100 marks
Practical Course in Nanoscience and Technology: I 100 marks

Semester II

Paper I: Top down manufacturing methods techniques for synthesis of Nanomaterials 100 marks
Paper II: Bottom up synthesis of Nanostructures 100 marks
Paper III: Physicochemical methods for characterisation of nanomaterials 100 marks

Any One Elective out of following

Elective Paper I:Genetics and Molecular Biology 100 marks
Elective Paper II: Quantum Mechanics 100 marks
Practical Course in Nanoscience and Technology: II 100 marks

Part I : Total Marks: 1000

PART-II (Semester III and IV)

Semester III

Paper I: Imaging techniques for Nanotechnology 100 marks

Any Three Electives out of following

Elective Paper I: Semiconductor nanostructures and nanoparticles 100 marks
Elective Paper II: Surface and Colloidal Chemistry 100 marks
Elective Paper III: Structural Nanobiosciences and Genetic Engineering 100 marks
Elective Paper IV: Nanoelectronics and sensors 100 marks
Elective Paper V: Nanotechnology in Health Care 100 marks
Practical Course in Nanoscience and Technology: III 100 marks
Research Project on Nanomaterials (Synthesis, characterisations and applications): 25 marks (Internal Examination)

Semester IV

Paper I: Toxicological, safety and ethical aspects of nanotechnology 100 marks

Any two Electives out of following

Elective Paper I: Nanotechnology for Energy Systems 100 marks
Elective Paper II: Carbon Nanotechnology 100 marks
Elective Paper III: Tissue Engineering and Regenerative Medicine 100 marks

Research Project on Nanomaterials (Synthesis, characterisations and applications): External Examination-150 marks, Internal Examination- 25 marks

Part II : Total Marks: 1000

Total Marks: 2000

SEMESTER – I

Paper I: Introduction to Nanoscience and Nanotechnology

Introduction to Nanoscience; History and Scope, Interdisciplinary nature, Structure of nanomaterials, Transition in physical, chemical, thermal, optical, electrical, magnetic properties of nanomaterials, role of dimensions in nanomaterials. Characteristic scale for quantum phenomena, Length scales – de Broglie wavelength & exciton Bohr radius, jellium model,

Classification of nanostructures / Nanoscale architecture- nanoparticles, nano-clusters, nanotubes, nanowires and nanodots. Quantum wells, quantum wires, quantum dots, fullerenes, graphite, carbon nanotubes, inorganic nanowires, nanoparticles, core-shell nanoparticles.

Nanofluidics and surfaces: liquid structure near solid-liquid interfaces

Hydrodynamic boundary condition: slip vs.non-slip, electro kinetic effects (electrophoresis, electro osmotic effect, electro viscous effect), surface reconstruction, dangling bonds and surface states.

Overview of relevant semiconductor physics - Quantum confinement in semiconductor nanostructures - The electronic density of states - Fabrication techniques - Physical processes in semiconductor nanostructures - The characterisation of semiconductor nanostructures - Applications of semiconductor nanostructures

Applications to Nanoelectromechanical systems (NEMS), Nano-optoelectronic materials and devices, medicine and pharmacology applications, thin-films, nanoscale devices – Transistors, FETs, quantum dot lasers and others. Drexler-Smalley debate -realistic projections.

Reference

1. Nanoscale Science and Technology, Robert W. Kelsall, Ian W. Hamley and Mark Geoghegan, John Wiley & Sons, Ltd., UK, 2005.

2. Introduction to Nanotechnology, Charles P. Poole Jr and Frank J. Owens, Wiley Interscience, 2003.

3. Bio-Inspired Nanomaterials and Nanotechnology, Edited by Yong Zhou, Nova Publishers.

4.Nano:The Essentials: Understanding Nanoscience and Nanotecnology, T.Pradeep, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2008.

Paper II: Chemistry of materials

Name Reactions: Wurtz reaction - Claisen and Dieckmann condensation - Williamson reactions. Different mechanisms of aromatic nucleophilic substitution - Ziegler alkylation - Chichibabin reaction - Cine substitution - diazonium group as leaving group. Friedel Crafts alkylation - Friedel Crafts arylation (Scholl reaction) and acylation - Jacobsen reaction - formylation with (i) disubstituted formamides(Vilsmeyer- Haack reaction) (ii) zinc cyanide and HCl (Gattermann reaction) (iii) chloroform (Reimer - Tiemann reaction) - carboxylation with (i) carbonyl halides (ii) carbon dioxide (Kolbe Schmidt reaction) - amidation with isocyanates - hydroxyalkylation (hydroxyalkyl - dehydrogenation)- cyanodehydration of aldehydes and ketones (Bradsher reaction and Bischer - Napieralski rection) - haloalkylation - aminoalkylation and amido alkylation - thioalkylation -acylation with nitriles (Hoesch reaction) - cyanation - hydroxylation.

Inorganic Chemistry: Term states of dn ions - electronic spectra of coordination compounds - selection rules - band intensities and band widths - energy level diagrams of Orgel and Tanabe - Sugano - spectra of Ti3+, V3+, Ni2+, Cr3+, Co2+, Cr2+ and Fe2+ - calculation of 10Dq and B for V3+(oct) and Ni2+(oct) complexes. Magnetic properties of coordination compounds - change in magnetic properties of complexes in terms of spin orbit coupling - temperature independent paramagnetism - spin cross over phenomena.

Reactions in solution: Comparison between gas phase and solution reactions. Cage effect. The influence of the solvent on the reactions between ions and reaction between ions and neutral molecules. Influence of ionic strength on rates of reactions in solution. Significance of volume

and entropy of activation. Secondary salt effect. Kinetic treatment of complex ion. Parallel reactions of the same order (first or second, parallel first and second order reactions. Reversible reaction of the same order (first or second order). First order forward and second order backward. Consecutive first order reactions, steady state and rate determining step (or equilibrium) approximation of complex reactions. Chain reactions and explosions.

Homogeneous catalysts: Specific and general acid-base catalysis. Bronsted catalysis law. Acidity functions. Enzyme catalysis (single substrate reactions only). Michaelis-Menton kinetics. Influence of PH and temperature on enzyme catalysis. Surface Phenomenon and Heterogeneous catalysts Adsorption and free energy relation at interfaces. Gibb‘s adsorption isotherm. Physisorption and chemisorption. Adsorption isotherms (Langmuir and BET). Measurement of surface area. Kinetics of heterogeneous catalysis (Langmuir hinshelwood mechanism and Eley-Rideal mechanism). Semi conductor catalysis.

Polymers and composites: number average and weight average molecular weights of polymers. Determination of molecular weights. Kinetics of polymerization, molecular and free radical mechanism. Polymerisation in solution. Brief Chemistry and Technology of Epoxies, polyesters, polyurethanes, silicones, acrylics, hybrid polymers, polymer and ceramic composites

References

1. Jerry March, Advanced organic chemistry - Reactions, mechanism and structure, Mc Graw Hill Kogakusha Ltd., 1977.
2. Lowry and Richardson, Mechanism and theory in organic chemistry, Harper & Row Publishers, New York 1981.
3. Mukergee and S. P. Singh, Reactions mechanisms in organic chemistry, Mc Millan 1976.
4. Raj K.Bansal Organic Chemistry Reaction mechanisms,Mc.Graw-Hill Publishing Company Ltd,2006
5. P.W.Atkins, Physical Chemistry 4. W.J.Moore, Physical Chemistry, Longmans
6. A.A.Frost and R.G.Pearson, Kinetics and Mechanism, Wiley Eastern, Pvt. Ltd.
7. F.W. Billmeyer, Text book of Polymer science, Wiley- Interscience.
8. Inorganic Chemistry - Principles of structure and reactivity, Fourth Edition J. E. Huheey, E. A. Keiter and R. L. Keiter - Addition Wesley Publishing Co, NY, 1993.
9. Advanced Inorganic Chemistry - F. A. Cotton and G. Wilkinson 3. Mechanism of Inorganic reactions - F. Basolo and R. G. Pearson

Paper III: Physics of Materials

Atomic Structure and Bonding: Atomic Bonding in solids, Types of bond: Mettalic,Ionic, Covalent and Van der waals bond; Hybridisation; H bonding, Molecular orbital theory for simple molecules such as diatomic molecule.

Structure and properties crystalline materials, Bravais Lattices, crystallographic directions, Crystallographic Planes, Miller Indices. Lattice vibrations, Elastic and atomic force constants; Dynamics of a chain of similar atoms and chain of two types of atoms; optical and acoustic modes; interaction of light with ionic crystals. Einstein's and Debye's theories of specific heats of solids.

Band theory of solids, transport properties of materials

Magnetic Properties : Fundamentals of magnetism. Different kind of magnetism in nature: Dia, Para, Ferro, Antiferro, Ferri, Superpara.

Important properties in relation to nanomagnetism. Magnetic nanoparticles Band Structure, The Bloch Function, The Bloch Theorem, Band Structure in 3-Dimensions, modification of dielectric properties with nanoparticles, Metals and Semiconductors.

Optical Properties: Optical absorption & transmission, Photoluminescence, Fluorescence, Phosphorescence, Electroluminescence.

Mechanical and Thermal Properties: Young's modulus, Bulk Modulus, Modulus of rigidity.
Tensile Testing and Tensile Strength, Yield Strength, Breaking Strength, Plastic Deformation, True Stress and Strain Bend Testing.
Dielectric properties of materials, Electronic, ionic and dipolar polarizability, local fields, induced and oriented polarization –molecular field in a dielectric; Clausius-Mosotti relation.
Superconductivity: Introduction (Kamerlingh-Onnes experiment), effect of magnetic field, Type-I and type-II superconductors, Isotope effect. Meissner effect. Heat capacity. Energy gap. Ideas about High-Tc superconductors.

Paper IV: Cell Biology and Biochemistry of Materials

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, Neurotransmission, neuromuscular junction. Extra cellular matrix – cell to cell and cell matrix adhesion – selectins, Integrins, cadherins, gap junctions.
Mitochondria – structure, biogenesis; Chloroplast – structure, biogenesis; Molecular events of electron transport chain, ATP synthesis, photosynthesis and photorespiration. Structure of Endoplasmic reticulum, Golgi complex, lysosomes; protein synthesis and post translational modification; of proteins vesicular transport and import into cell organelles
Enzyme kinetics (negative and positive cooperativity); Regulation of enzymatic activity; Enzyme catalysis in solution. kinetics and thermodynamic analysis, effects of organic solvents on enzyme catalysis and structural consequences. Active sites; Coenzymes: activators and inhibitors, kinetics of enzyme inhibitors, isoenymes, allosteric enzymes; Ribozyme, hammer head, hair pin and other ribozymes, strategies for designing ribozymes. Abzyme: structure and drug targets (enzymes and receptors); Prodrug delivery using enzymes; Bioluminescence
Sugars - classification and reactions. Polysaccharides: classification, occurrence, isolation, purification, properties and biological reactions. Structural features of homoglycans, heteroglycans and complex carbohydrates.Methods for compositional analysis.
Proteins: Amino acids and peptides-classification, chemical reactions and physical properties. Peptide bond, Primary structure of proteins, structural comparison at secondary and tertiary levels (Ramchandran map), conformation of proteins and polypeptides (secondary, tertiary, quaternary and domain structure),Purification and criteria of homogeneity:protein folding-biophysical and cellular aspects.
Lipids: Classification, structure and functions. Triglycerides; Phospholipids; Steroids and terpenes. Glyco and lipoproteins-structure and function. Role of lipids in biomembranes. Nucleic acids: Structure of double stranded DNA (B, A, C, D, T and Z DNA). The biological significance of double strandedness, sequence dependent variation in the shape of DNA. Physical properties of double stranded DNA Types of RNAs and their biological significance. DNA bending, DNA supercoiling. Conformational properties of polynucleotides, secondary and tertiary structural features and their analysis.

References

1. Molecular cell Biology, Darnell, Lodish, Baltimore, Scientific American Books, Inc., 1994.
2. Molecular and cellular Biology, Stephen L.Wolfe, Wadsworth Publishing company, 1993.
3. Biochemistry, Christopher K. Mathews, Kensal E. van Holde, Kevin G. Ahern, 3rd Edition, Pearson Education, 2000.
4. Principles of Biochemistry, Abraham White, Philip Handler, Emil L. Smith., McGraw – Hill International book Company, 8th Edition, 1973. 3. Principles of Biochemistry, Lehninger , Nelson, Cox, CBS publishers and distributors, New Delhi, 2004.

5. Fundamentals of Biochemistry, Donald Voet, Akif Uzman, Judith G. Voet, Charlotte W. Pratt, John Wiley and Sons, New York, 2008.
6. Biochemistry, Geoffrey L. Zubay , WCB publishers, 1998. 6. Harper's Biochemistry, R.K.Murray, D.K.Granner, P.A.Mayes and V.W Rodwell,24th edition, Stamford, 1996. 7. Biochemistry – Lubert Stryer, 1995.

Practical Course in Nano Science and Technology I

Section A: (Any 5 Experiments)
i. Demonstration on safety aspects of handling of nanoparticles
ii. Preparation and testing of $CaCO_3$ by Situ matrix deposition.
iii. Preparation and testing of silver and Gold nanoparticles by chemical route, Brust synthesis of nanoparticles – gold and silver nanoparticles,
iv. Synthesis of ZnS nanoparticles by chemical route and determination of band structure through UV-Vis spectroscopy and FTIR Spectroscopy.
vi. Synthesis and testing of Cadmium Selenide Quantum dots of various sizes.
Preparation and testing of CaCo3 by Situ matrix deposition / electrolysis.
vii. Preparation and testing of Iron oxide by Flame Pyrolysis
viii. Micellar route to Nano rod synthesis.
ix. Synthesis and testing of Antimony oxychloride by matrix mediated growth
Section B (Any 3 Experiments):
i. Synthesis and Characterization of Silver Nanoparticles by Soil Fungus.
ii. Synthesis of Gold Nanoparticles using Actinomycetes and Fungus.
iii. Green synthesis of ZnO and CdS by bacteria.
iv. Study of Nanosilver and Protein interaction by Spectroscopic Methods.
v. Determination of Antimicrobial Activity of Fe And Cu Nanoparticles.

Semester II

Paper I: Topdown manufacturing methods

Introduction to micro fabrication and Moore's law – importance of lithographic techniques different types of lithographic techniques -Optical projection lithography- Photomask- Binary mask- Phase shift mask -Optical immersion lithography- Maskless optical projection lithography- Zone plate array lithography- Extreme ultraviolet lithography.

E-Beam and Ion Beam Lithography: Principle and instrumentation - Scanning electron-beam lithography- Mask less (ML2) EBL-parallel direct-write e-beam systems-E-beam projection lithography - PREVAIL Xray lithography - Focused ion beam lithography - Ion projection lithography - Masked ion beam direct structuring-Nanoimprint lithography and soft lithography- Nanoimprint lithography - Soft lithography- Dip-Pen lithography.

Etching Techniques: Reactive ion etching (RIE) Magnetically enhanced RIE- Ion beam etching - Wet etching of silicon - Isotropic etching - Anisotropic etching – Electrochemical etching - Vapor phase etching - Dry etching- Other etching techniques.

Ball Milling Technique: Nanopowders produced using micro reactors; Nanocrystalline ceramics by mechanical activation; Formation of nanostructured polymers.

Machining Processes: Micromilling/microdrilling/microgrinding processes and the procedure for selecting proper machining parameters with given specifications- EDM micro machining, laser micro/nanomachining- models to simulate micro/nanomachining processes using molecular dynamics techniques-Wet chemical etching - Dry etching - Thin film and sacrificial processes.

Inert gas condensation, Arc discharge, RF-plasma, Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Molecular beam epitaxy,

References

1. M. J. Jackson, “Micro fabrication and Nanomanufacturing”, CRC Press, 2005.
2. P.Rai-Choudhury, “Handbook of Micro lithography, Micro machining, and Micro fabrication”, Vol. 2, SPIE Press, 1997.
3. M. Madou, “Fundamentals of Microfabrication,” CRC Press, 1997.
4. G.Timp, “Nanotechnology”, AIP press, Springer-Verlag, New York, 1999.

Paper II: Bottom up synthesis of nanostructures

Thin Film Technologies – I

CVD Chemical vapor deposition –Atmospheric pressure CVD(APCVD) – Low pressure CVD (LPCVD) - Plasma enhanced chemical vapor deposition (PECVD) or - The HiPCO method - Photo-enhanced chemical vapor deposition (PHCVD)- LCVD Laser–Induced CVD.

Thin Film Technologies – II

Physical vapor deposition- Sputter technologies- Diode sputtering - Magnetron sputtering - Ion beam (sputter) deposition, ion implantation and ion assisted deposition – Cathodic arc deposition - Pulsed laser deposition.

Epitaxial Film Deposition Methods

Epitaxy, Different kinds of epitaxy- Influence of substrate and substrate orientation, mismatch, MOCVD Metal Organic Chemical Vapor Deposition - CCVD Combustion Chemical Vapor Deposition - ALD Atomic Layer Deposition -LPE Liquid phase epitaxy - MBE Molecular Beam Epitaxy.

Chemical Methods

Sol-gel synthesis –different types of coatings -Spin coating- Self assembly- (Periodic) starting points for self-assembly- Directed self-assembly using conventional lithography- Template self-assembly-Vapor liquid solid growth, Langmuir-Blodgett films, Micelles and microemulsions.
DNA self assembly.
Solvothermal synthesis, Photochemical synthesis,Electrochemical synthesis, Nanocrystals of semiconductors and other materials by arrested precipitation, Thermolysis routes, Sonochemical routes, Liquid-liquid interface, Hybrid methods,Solvated metal atom dispersion, Post-synthetic size-selective processing. Sol-gel,

Printing Technologies

Screen printing- Inkjet printing- Gravure printing and Flexographic printing- Flex graphic printing- Gravure printing- Roll-to-Roll techniques.

Biological Methods of Synthesis- Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Synthesis process and application, Role of plants in nanoparticle synthesis.

References

1. G. Cao, “Nanostructures & Nanomaterials: Synthesis, Properties &Applications” Imperial College Press, 2004.
2. W.T.S. Huck, “Nanoscale Assembly: Chemical Techniques (Nanostructure Science and Technology)”,
3. “Handbook of Nanoscience, Engineering and Technology”, Kluwer publishers, 2002.

Paper III: Physicochemical Methods for Characterization of Nanomaterials

X-Ray Diffraction

X-ray powder diffraction – single crystal diffraction techniques - Determination of accurate lattice parameters - structure analysis - profile analysis - particle size analysis using Scherer formula.

Thermal Analysis Methods

Principle and Instrumentation of Thermogravimetry; Differential Thermal Analysis and Differential scanning calorimetry-Importance of thermal analysis for nanostructures.

Qualitative and Quantitative Analysis

Electron Energy Loss Spectroscopy; High Resolution Imaging Techniques- HREM, Atom probe field ion microscopy-X-Ray Photoelectron Spectroscopy, X-Ray Characterization of Nanomaterials – EDAX and WDA analysis – EPMA – ZAP corrections.

Spectroscopic Techniques

Introduction to Molecular Spectroscopy and Differences-With Atomic Spectroscopy- Infrared (IR) Spectroscopy and Applications- Microwave Spectroscopy- Raman Spectroscopy and CARS Applications-Electron Spin Resonance Spectroscopy; New Applications of NMR Spectroscopy; Dynamic Nuclear Magnetic Resonance; Double Resonance Technique.

Nanoindentation

Nanoindentation principles- elastic and plastic deformation -mechanical properties of materials in small dimensions- models for interpretation of nanoindentation load displacement curves-Nanoindentation data analysis methods-Hardness testing of thin films and coatings- MD simulation of nanoindentation.

References

1. B. D.Cullity, "Elements of X-ray Diffraction", 4th Edition, Addison Wiley, 1978.
2. M. H.Loretto, "Electron Beam Analysis of Materials", Chapman and Hall, 1984.
3. R.M.Rose, L.A.Shepard and J.Wulff, "The Structure and Properties of Materials", Wiley Eastern Ltd,
4. B.W.Mott, "Micro-Indentation Hardness Testing", Butterworths, London, 1956.
5 Advanced X-ray Techniques in Research and Industries - A. K. Singh (Editor)
6 X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition - Harold P. Klug, Leroy E. Alexander
7 Introduction of X-ray Crystallography- M.M. Woolfson
8 Fabrication of fine pitch gratings by holography, electron beam lithography and nanoimprint lithography (Proceedings Paper) Author(s): Darren Goodchild; Alexei Bogdanov; Simon Wingar; Bill Benyon; Nak Kim; Frank Shepherd
9. Microfabrication and Nanomanufacturing- Mark James Jackson

Elective Paper I: Genetics and Molecular Biology

Genome Organization in prokaryotes: genome of bacteria, bacteriophage and viruses, plasmids. The fine structure of a prokaryote gene; Genetics of bacteria: transformation, conjugation, transduction; the genetic map of E.coli genetic recombination. Genetics of viruses: Life cycle of virulent bacteriophages, temperate phages and prophage; genetic recombination in phages; mapping genes in phage lambda; The RNA phages, tumor viruses and cancer; viroids.

Genome Organization in Eukaryotes, variation in chromosome number: haploidy, polyploidy, aneuploidy. Variation in chromosome structure: deficiency of deletion, duplication, translocation, inversion and B-chromosome. The fine structure of Eukaryote gene; Allele, Multiple allele, complementation test,pseudo alleles, Genetic mapping: Molecular marker,somatic cell hybrids, split genes, overlapping genes; transposons. Linkage and crossing over; The three point cross; double crossing over, cytological basis of crossing over; sex linkage; recombination in Neurospora.

Principles of Mendelian inheritance; Mendel's experiments-monohybrid, dihybrid, trihybrid and multihybrid crosses. Interaction of genes: incomplete dominance, codominance, epistasis, complementary genes, duplicate genes, polymeric genes, modifying genes; Pleotrophy, genome imprinting, inheritance and lethal genes. Environment and gene expression: penetrance and expressivity; temperature, light, phenocopies. Quantitative or polygenic inheritance: Inheritance

of kernel color in wheat; corolla length in tobacco, skin color inheritance in man, transgressive and regressive variation. Multiple alleles; Sex determination; Extra chromosomal inheritance.(Episome, mitochondria and chloroplast)

Human Genetics: Introduction to Human Genetics. Human Chromosomes: Structure and organization of DNA; Normal human karyotype: Paris Nomenclature; Chromosomal aberration: Numerical: Aneuploidy, Polyploidy (Eg: Turner, Down & Klinefelter Syndromes). Structural: Translocation, Duplication, Inversion, Ring Chromosome and Deletion (Eg: Cri-du-chat syndrome). Others: Mosaic, Chimera [Individual with two cell lines] Mendelian Traits: Straight hair, Curly hair, Blue and Brown colour of the eyes, Rolling of the tongue, attached and free ear lobes and Hypertrichosis.

References

1. The science of Genetics, Alan G. Atherly, Jack. R. Girton, Jhon. F. Mc Donald, Sounders college publishers, 1999.
2. Genes VII, Benjamin Lewin, Oxford University Press, 2000.
3. A primer of population genetics, Hartl. D.L, 3rd edition, Sinauer associates inc. Sunderland, 2000.
4. Molecular cell Biology, Darnell, Lodish, Baltimore, Scientific American Books, 1994.
5. Molecular and cellular Biology, Stephen L.Wolfe, Wadsworth Publishing Company, 1993.
6. Human genetics, A.Gardner, R.T.Howell and T.Davies, Vinod Vasishtha for Viva Books private limited, 2008. Published by arrangement with Scion publishing limited Mloxham Mill, Baraford Road, Bloxham Ox25 4FF, UK.

Elective Paper 2: Quantum Mechanics

Origin of Quantum Theory**:** Basic Principles of Quantum Mechanics, Classical Mechanics – Drawbacks, The work of Planck: Blackbody radiation, The work of Einstein: The photoelectric effect, The work of Bohr: A quantum theory of atomic states (Bohr Model of hydrogen atom), The Stern – Gerlach Experiment: Angular Momentum and spin, The De Broglie hypothesis and Davission – Germer Experiment

The Wave Function and the Uncertainty Principle (BJ): Wave- particle duality, Interpretation of wave function (Probability & Super position principle), Wave function for particles having a definite momentum, Wave packet, The Heisenberg uncertainty principle

Discrete Eigen Value, The Hydrogen Atom – Single atom and Many Electron Atoms systems - Harmonic oscillator–Hydrogen atom wave equations -space quantization-discussion of bound states-parity-Angular momentum-Eigen functions-Rigid rotator application to diatomic molecules-energy level spacing

The Schrodinger Equation, Schrodinger equation in one dimension, Schrodinger in three dimensions, Probability current density

The Postulates of Quantum Mechanics: Observables & operators, Measurements in quantum mechanics, The state function & Expectation values.

Nanoscale Materials and Quantum Mechanics: Quantum Confinement, Size Quantization, Three Dimensional System (Bulk), Two Dimensional System (Nanostructured Plane), One Dimensional System (Quantum Wire), Zero Dimensional System (Quantum Dots), Varieties of Quantum Dots.

References:

1. Introductory Quantum Mechanics(Fourth Edition): Richard L. Liboff
2. Quantum Mechanics(Second Edition):B.H.Bransden & C.J.Joachain
3. Quantum Mechanics: Powell and Craseman
4. Advanced Quantum Mechanics: Satya Prakash . Kedarnath Ram Nath, Meerut.
5. Quantum Mechanics: Gupta, Kumar, Sharma.. Sultan Chand & Sons
6. Quantum Mechanics: Chatwal and Anand.. Himalaya Publishing Co.

7. Quantum Mechanics: L. I. Schiff, McGraw-Hill

Practical Course in Nano Science and Technology- II

Any ten experiments designed on the basis of following
Synthesis of different aspect ratio of Metal-oxide Nanowires, Fabrication of ferrofluids by chemical methods, core shell nanoparticles, Preparation and testing of polymer & rubber Nano composites, Pharmaceutical Nanoparticles- Preparation and testing,
Spectroscopy of Nanomaterials: UV-Visible spectroscopy, Photoluminescence spectroscopy, IR spectroscopy – FTIR and ATR,
Measurement of Optical Properties: Absorption and emission studies, refractive index and dispersion measurements, Magneto-optic properties of ferrofluids, Nonlinear optical transmission properties, Study of Optical Limiting,
Crystalline phase of analysis of Nanoparticles by DSC at ambient & low Temp condition.
Thermal degradation characteristics by TGA, Rheology of dispersion of Nanoparticles by Surface & pore volume determination of Nano particles, Contact Angle Measurement, Demonstration on safety aspects of handling of nanoparticles

SEMESTER III

Paper I is compulsory. Select any three Elective papers

Paper I: Imaging Techniques for Nanotechnology

Optical Microscopy: Optical microscopy- Use of polarized light microscopy – Phase contrast microcopy – Interference Microscopy – hot stage microscopy - surface morphology – Etch pit density and hardness measurements.

Scanning Electron Microscopy

Basic design of the scanning electron microscopy – Modes of operation– Backscattered electrons – secondary electrons- X-rays – typical forms of contrast– Resolution and contrast – enhancement – Specimen Preparation, Replicas Various-application of SEM.

Transmission Electron Microscopy

Basic principles - Modes of operation – Specimen preparation – Diffraction in imperfect crystals – Dislocations – precipitates – Structure of Grain boundaries and interfaces- HRTEM use in nanostructures.

Atomic Force Microscopy

Basic concepts-Interaction force-AFM and the optical lever- Scale drawing- AFM tip on nanometer scale structures- force curves, measurements and manipulations-feedback control-different modes of operation –contact, non contact and tapping mode-Imaging and manipulation of samples in air or liquid environments-Imaging soft samples. Scanning Force Microscopy-Shear force Microscopy-Lateral Force Microscopy-Magnetic Force microscopy.

Scanning Tunneling Microscopy

Principle- Instrumentation- importance of STM for nanostructures – surface and molecular manipulation using STM -3D map of electronic structure.

References

1. J.Goldstein, D. E. Newbury, D.C. Joy, and C.E. Lym, “Scanning Electron Microscopy and X-ray Microanalysis”, 2003.
2. S.L. Flegler, J.W. Heckman and K.L. Klomparens, “Scanning and Transmission Electron Microscopy: A Introduction”, WH Freeman & Co, 1993.
3. P.J.Goodhew, J.Humphreys, R.Beanland, “Electron Microscopy and Analysis”
4. R.Haynes, D.P.Woodruff and T.A.Talchar, “Optical Microscopy of Materials”,
Cambridge University press, 1986.

5 Scanning Probe Microscopy: Analytical Methods (NanoScience and Technology)-Roland Wiesendanger
6 Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)-David B. Williams and C. Barry Carter
7Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton

Elective Paper I: Semiconductor Nanostructures

Semiconductor fundamentals: Introduction to Semiconductor physics – Fabrication techniques – Semiconductor nanostructures – Electronic structure and physical process – Principles of semiconductor nanostructures based electronic and electro-optical devices – Semiconductor Quantum Dots – Quantum Lasers – Quantum Cascade Lasers – Quantum Dot Optical Memory.

Semiconductor nanoparticle synthesis

Cluster compounds, quantum-dots from MBE and CVD, wet chemical methods, reverse micelles, electro-deposition, pyrolytic synthesis, self-assembly strategies.

Physical properties

Melting point, solid-state phase transformations, excitons, band-gap variations-quantum confinement, effect of strain on band-gap in epitaxial quantum dots, single particle conductance.

Semiconductor nanowires

Fabrication strategies, quantum conductance effects in semiconductor nanowires, porous Silicon, nanobelts, nanoribbons, nanosprings.

Semiconductor nanostructures for Optoelectronics

Optical luminescence and fluorescence from direct band gap semiconductor nanoparticles, Quantum Dot Infrared Photodetectors - QD and QDIP, Structure Growth and Characterization, GaAs Capped Large and Small InAs QDs, AlGaAs Capped Large InAs MQD QDIP Structures, QDIP Device Characteristics Device Structures Detectors, Quantum Dot Lasers: Theoretical Overview, Dimensionality and Laser Performance, Advantages of an Idealized QD Laser, Progress in fabricating QD Lasers, State-of the-Art Complications, High-Speed Quantum Dot Lasers, MBE Growth of Self-Organized QDs, Characteristics of High-Speed Tunneling-Injection QD Lasers, Room Temperature DC Characteristics, Temperature-Dependent DC Characteristics, High-Speed Modulation Characteristics, Zinc Oxide-Based Nanostructures, General Properties of ZnO, ZnO One-Dimensional Nanostructures, Growth Mechanisms, Growth Techniques, Structural Characterizations, Optical Characterizations,

REFERENCES

1 Encyclopedia of Nanotechnology-Hari Singh Nalwa
2 Springer Handbook of Nanotechnology -Bharat Bhusan
3 Handbook of Semiconductor Nanostructures and Nanodevices Vol 1-5-A. A. Balandin, K. L. Wang.
4 Nanostructures and Nanomaterials -Synthesis, Properties and Applications - Guozhong

Elective Paper II: Applied Colloid and Surface Chemistry

Classification of Surfactants: anionic, cationic, non-ionic, amphoteric, Other types: Gemini, polymeric.

Synthesis, analysis and properties of few surfactants: alcohol sulphates, sulphosuccinates, sucrose polyesters, nitrogen derivatives, betaines

Introduction to the nature of colloidal solutions and various surface phenomenon: Surface Tension, CMC, Wetting, Solubilisation, Dispersion, Detergency, Foam, Aerosols,

Thermodynamics of Adsorption

Theories of entropic and electrical double layer stabilisation, concept of electrokinetic potential

Surfactants and Self-assembly

Emulsions and Microemulsions
Charged Colloids
Van der Waals forces and Colloid Stability
Bubble coalescence, Foams and Thin Surfactant Films
Role of surfactants in synthesis of nanoparticles- detailed discussion on mechanism and growth aspects

References:

1. Richard M.; Marilyn E. K.; Pashley. Applied Colloid and Surface Chemistry, *John Wiley and Sons Ltd*, 2004, Chichester, UK.
2. James, R.; Carlos, K. J.; Montilla, L.; Pandey, S.; Shah, D. O. Handbook of Applied Surface and Colloid Chemistry, *John Wiley and Sons Ltd*, 2002, Chichester, UK.
3. Vincenzo T. L. Controlled Synthesis of Nanoparticles in Microheterogeneous Systems, 2006, *Springer*, New York.

Elective Paper III: Structural Nanobiosciences and Genetic Engineering

Molecular Tools of Genetic Engineering -I
Genetic engineering concepts, Restriction endonucleases: types and mode of action
Nucleases: exo-and endo-nucleases (DNAses, RNAses), DNA-ligases, Alkaline phosphatases and DNA modifying enzymes. DNA and RNA markers. Host cells: prokaryotic hosts and eukaryotic hosts
Molecular Tools of Genetic Engineering -II
Cloning and expression vectors: Choice of vectors, Plasmids, Cosmids,Artificial chromosomes, Shuttle vectors and Phagemids. Ti and Ri plasmids: General features, basis of tumor formation, mechanism of DNA transfer, role of virulence genes, use of reporter genes. Vectors in human gene therapy (viral and non viral vectors). Identification of Recombinant DNA (Direct and indirect methods)
DNA Nanotechnology :
DNA as functional template for nanocircuitry; Protein based nanocircuitry; Neurons for network formation. DNA nanostructures for mechanics and computing and DNA based computation.
DNA based nanomechanical devices.
Green synthesis of Nanomaterials: Microorganisms for synthesis of nanomaterials and for toxicity detection-Natural and artificial synthesis of nanoparticles in microorganisms. Use of microorganisms for nanostructure formation, Testing of environmental toxic effect of nanoparticles using microorganisms. Nanobio Systems-Nanoparticle-biomaterial hybrid systems for bioelectronic devices. Bioelectronic systems based on nanoparticle-enzyme hybrids.

Elective paper IV: Nanoelectronics and Sensors

Semiconductor nanodevices:
Single-Electron Devices; Nano scale MOSFET – Resonant Tunneling Transistor – Single Electron Transistors; Single-Electron Dynamics; Nanorobotics and Nanomanipulation; Mechanical Molecular Nanodevices; Nanocomputers: Theoretical Models; Optical Fibers for Nanodevices; Photochemical Molecular Devices; DNA-Based Nanodevices; Gas-Based Nanodevices; Micro and Nanomechanics.

Electronic and photonic molecular materials
Preparation –Electroluminescent Organic materials -Laser Diodes -Quantum well lasers:-Quantum cascade lasers-Cascade surface-emitting photonic crystal laser-Quantum dot lasers-Quantum wire lasers:-White LEDs -LEDs based on nanowires LEDs based on nanotubes-LEDs based on nanorods High Efficiency Materials for OLEDs-High Efficiency Materials for OLEDs -Quantum well infrared photo detectors.

Molecular Electronics Components
Electronic transport in 1, 2 and 3 dimensions – Quantum confinement -Energy subbands – Quantum wells – Quantum wires – Quantum dots – Device miniaturization.
Nanodevices: Nanoelectronic and Nanocomputers – Quantum Mechanical Tunnel Devices – Characterization of switches – Complex molecular devices – Organic/inorganic based rectifying diode switches – LEDs, TFTs – Single Electron Devices – Consequences of Moore's law.
Nanoelectronic Architectures
Nanofabrication – Nanopatterning of Metallic/Semiconducting nanostructures (e-beam/X-ray, Optical lithography, STM/AFM-SEM & Soft-lithography) – Nanophase materials – Self-assembled Inorganic/Organic layers – Molecular devices – Logic switches – Interface engineering – Properties (Self-organization, Size-dependent) – Limitations.
Computational Nanotechnology
Monte Carlo Simulations-Computational methods and Simulations from ab initio to multiscale Modeling-Modeling of Nanodevices-Applications and Example Problems
Sensors : Fundamentals of sensors, biosensor, micro fluids, MEMS and NEMS, Packaging and characterization of sensors. Sensors for aerospace and defense: Accelerometer, Pressure Sensor, Night Vision System, Nano tweezers, nano-cutting tools, Integration of sensor with actuators and electronic circuitry, Sensor for bio-medical applications: Cardiology, Neurology and as diagnostic tool, For other civil applications: metrology, bridges etc. Biosensors. Clinical Diagnostics, generation of biosensors.
THERMAL SENSORS: Thermal energy sensors -temperature sensors, heat sensors-Electromagnetic sensors-electrical resistance sensors, electrical current sensors, electrical voltage sensors, electrical power sensors, magnetism sensors -Mechanical sensors -pressure sensors, gas and liquid flow sensors, position sensors -Chemical sensors -Optical and radiation sensors.
GAS SENSOR MATERIALS
Criteria for the choice of materials, Experimental aspects – materials, properties, measurement of gas sensing property, sensitivity; Discussion of sensors for various gases, Gas sensors based on semiconductor devices.
BIOSENSORS
Principles-DNA based biosensors – Protein based biosensors – materials for biosensor applications-fabrication of biosensors—future potential.
REFERENCES

1 W. Ranier, "Nano Electronics and Information Technology", Wiley, (2003).
2 K.E. Drexler, "Nano systems", Wiley, (1992).
3 M.C. Pettey, "Introduction to Molecular Electronics".

Elective Paper V: Nanotechnology in healthcare

Human anatomy – Form function and physiology – Developmental prolog -principle of development – Neurophysiology – sensory physiology and muscle physiology -Trends in nanobiotechnology -Protein-and peptide-based compounds for cancer, diabetes, infectious diseases and organ transplant-therapeutic classes-focused pharmaceutical delivery systems.
Concept of nanomedicines Nano antimicrobials: Nanostructures for use as antibiotics; Diseased tissue destruction using Nanoparticles.
Methods for diagnosis and Improved medical diagnostics
Animation of the PCR -DNA Profiling -Cantilever Sensors -Targeted Drug Delivery Magnetic

Nanoparticles -Cancer cell targeting -Stem Cell Scaffolds -Electrochemical Impedance Spectroscopy (EIS) -Tethered Lipid Membranes.

Diagnostics using nanomaterial, Nanoparticles for bioanalytical applications.Nanodevices for sensing and therapy, Improved diagnostic products and techniques-i*n vivo* imaging capabilities by enabling the detection of tumors, plaque, genetic defects and other disease states-ability to control or manipulate on the atomic scale-Nanobot medical devices-logic and intelligence embedded into medical devices-standalone sensing and computing devices.

Prosthetic and medical implants

New generations of prosthetic and medical implants-artificial organs and implants-artificial scaffolds or biosynthetic coatings-biocompatibility and reduced rejection ratio-retinal, cochlear, and neural implants, repair of damaged nerve cells, and replacements of damaged skin, tissue, or bone.

Polymeric Medicines :Biomimetic synthesis of nanocomposite material, Use of synthetic nanocomposites for bone, teeth replacement. Biosensor and Biochips.

REFERENCES

1 Chemical Sensors and Biosensors; Brian, R Eggins; Wiley; New York, Chichester; 2002.

2 Biosensors and modern biospecific analytical techniques, Wilson & Wilson's Comprehensive Analytical Chemistry; Ed. L Gorton; Elsevier, Amsterdam, London; 2005.

3 The Immunoassay Handbook; Ed. David Wild; 3rd ed.; Amsterdam: Elsevier; 2005.

4 Electrochemical Methods: Fundamentals and Applications; Allen J Bard and Larry R Faulkner; Wiley, New York, Chichester : 2nd ed.; 2001.

5 Ultrathin Electrochemical Chemo-and Biosensors: Technology and Performance in Springer Series on Chemical Sensors and Biosensors; Volume Two; Ed. Vladimir M. Mirsky; Springer, Berlin; 2004

Practical Course in Nanoscience and Technology- III

Any eight experiments based on the following:

Synthesize single- and multi-walled carbon nanotubes (CNT) using the chemical vapor deposition method. Study and compare the structural and optical properties of single- and multi-walled carbon nanotubes (CNT),

X-ray diffraction – determination of structure, composition and estimation of particle size, Scanning Tunneling Microscopy, Atomic Force Microscopy for analysis of nanomaterials:

Determination of size and lateral dimensions of various samples (pollen grains, strands of hair) using a high magnification optical microscope.

Synthesis of SiO_2 polysphere film and morphology characterization using a Optical microscope.

Surface topography of a sputtered Au film/ freshly cleaved mica/ polymer film on glass using AFM; thickness across a step, noncontact mode, phase imaging

Scanning Tunneling Spectroscopy (STS) on Multi walled Carbon Nanotubes deposited on HOPG.

Use of Energy dispersive X-ray spectroscopy with SEM, and TEM in the analysis of nanomaterials

Semester IV

Paper I is compulsory. Select any two Elective papers.

Paper I: Toxicological, safety and ethical aspects of Nanotechnology

Concept of Nanotoxicology: Laboratory rodent studies -Ecotoxicologic studies – Methodology - for Nanotoxicology toxicity testing. Mechanism of nanosize particle toxicity -Reactive oxygen species mechanisms of NSP toxicity Interactions between Nanoparticles and Living Organisms: Mechanisms and Health Effects Interactions of Nanoparticles with Cells and their Cellular Nanotoxicology -Cytotoxicity of Ultrafine Particles -Cytotoxicity and Potential mechanism of Nanomaterials.

Human Exposure to Nanosized Materials:

Biological Activities of Nanomaterials and Nanoparticles -Respiratory Tract – Efficient deposition of inhaled NSPs. -Disposition of NSPs in the respiratory -Disposition of NSPs in the respiratory -Epithelial translocation -Translocation to the circulatory system -Neuronal uptake and translocation -Translocation of NSPs in the blood circulation to bone.

Risk Assessment and Execution: Portals of entry and target tissue – Risk assessment – Ethical – Legal and Social Implications -Nanoparticle Toxicology and Ecotoxicology, The Role of Oxidative Stress – Development of Test Protocols for Nanomaterials.

Sociological and Ethical Issues in Nanotechnology

Moral and societal problems that arise in the professional practice, Knowledge of relevant backgrounds for recognizing, analysing and reasoning in a socially-oriented way, Description and analysis of the responsibility with respect to philosophical, historical and juridical aspects. Professional codes, company interests, conflicting loyalties, legal obligations and competencies. Ethics. Rational argumentation and discussion. Individual and collective decision-making. Responsibility, uncertainty, ignorance, risks. Technological fix . Problems and possible solutions. Intellectual property and rights, patenting – need for patents, protection of knowledge, open-source versus patent, knowledge consortia and databases.

Elective paper I: Nanotechnology for Energy Systems

Nanotechnology for sustainable energy- Alternatives for the power production, Materials for light emitting diodes-batteries advanced turbines-catalytic reactors-capacitors-fuel cells.

Fuel cell: Types of fuel cells, detailed of mechanism, role of nanomaterials in enhancement in functioning, Merits and demerits of fuel cells. Batteries: Types of battries, operating mechanism of batteries, role of nanomaterials in improving their performance.

Capacitors and Super capacitors: Importance of capacitors, Functioning of capacitor, role of nanomaterials in enhancement in functioning.

Role of nanocatalysts in energy production in petrochemical refinery (Hydrotreating, Fischer Trops, etc.)

RENEWABLE ENERGY TECHNOLOGY

Energy challenges, development and implementation of renewable energy technologies - nanotechnology enabled renewable energy technologies -Energy transport, conversion and storage, Nano, micro and meso scale phenomena and devices.

MICRO FUEL CELL TECHNOLOGY

Micro-fuel cell technologies, integration and performance for micro-fuel cell systems thin film and microfabrication methods -design methodologies -micro-fuel cell power sources,

MICROFLUIDIC SYSTEMS

Nano-electromechanical systems and novel microfluidic devices -nano engines -driving mechanisms -power generation -microchannel battery -micro heat engine (MHE) fabrication - thermocapillary forces -Thermocapillary pumping (TCP) -piezoelectric membrane.

HYDROGEN STORAGE METHODS

Hydrogen storage methods -metal hydrides -size effects -hydrogen storage capacity hydrogen reaction kinetics -carbon-free cycle-gravimetric and volumetric storage capacities -hydriding/dehydriding kinetics -high enthalpy of formation -and thermal management during the hydriding reaction -distinctive chemical and physical properties multiple catalytic effects -degradation of the sorption properties -hydride storage materials for automotive applications.

References

1 J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.
2 Hydrogen from Renewable Energy Sources by D. Infield,
3 Fuel Storage on Board Hydrogen Storage in Carbon Nanostructures by R.A. Shatwell, Fuel cell technology handbook. Hoogers. CRC Press, 2003.
4 Handbook of fuel cells: Fuel cell technology and applications by Vielstich. Wiley, CRC Press, 2003.

Elective Paper II: Carbon Nanotechnology

Introduction; carbon molecules – nature of the carbon bond – new carbon structures; cabon clusters – small carbon clusters discovery of C60 – structure of C60 and its crystal – alkali doped C60 – superconductivity in C60 – large and smaller fullerenes – other buckyballs; carbon nanotubes – fabrication – structure – electrical properties – vibrational properties – mechanical properties; applications of carbon nanotubes – field emission and shielding – computers – fuel cells – chemical sensors – catalysis – mechanical reinforcement.

Carbon Nanotubes and Types. Electronic Properties of Nanotubes. Architecture of Carbon Nanotubes Carbon based Nanomaterials: Classification of Carbon ,Diamond-Type Carbon with Pure sp3,Configured Carbon Atoms Graphite-Type Carbon with Pure sp2 Carbon Configured Atoms: Intermediate Forms of Carbon Containing,Mixture of sp2 and sp3 Configured Carbon Atoms Synthesis of CNT:

Synthesis of Carbon Nanotubes by Chemical Vapor Deposition. Thermal CVD and PECVD. Applications for CVD/ PECVD grown nanotubes.

Elective Paper III: Tissue Engineering and Regenerative Medicine

Major physiologic systems of current interest to biomedical engineers: cardiovascular, endocrine, nervous, visual, auditory, gastrointestinal, and respiratory. Useful definitions, The status of tissue engineering of specific organs, including bone marrow, skeletal muscle, and cartilage. Cell biological fundamentals of tissue engineering, Artificial organs, Biomaterials, Biodegradable Polymers used in artificial organs and prostheses, inflammation, rejection, correction. Rheological properties of blood, blood viscosity variation, effect of shear rate, hematocrit, temperature and protein contents.

Artificial kidney : Brief of kidney filtration, basic methods of artificial waste removal, hemodialysis, equation for artificial kidney and middle molecule hypothesis. Hemodialysers: flat plate type, coil type and hollow fiber.

Artificial heart-lung machine: Brief of lungs gaseous exchange / transport, artificial heart-lung devices. Oxygenators: bubble, film oxygenators and membrane oxygenators. Gas flow rate and area for membrane oxygenators. Liver support system, artificial pancreas, blood and skin.

Rehabilitation Engineering: Impairments, disabilities and handicaps, Measurement and assessment. Characterizing engineering concepts in sensory and motor rehabilitation. Engineering concept in communication disorders. Rehabs for locomotion, visual, speech &

hearing. Artificial limb and hands, prosthetic heart valves. Externally powered and controlled orthotics and prosthetics. Myoelectric hand and arm prostheses. The marcus intelligent hand prostheses, gait study, spinal rehabilitation.

RESEARCH PROJECT (III Sem-Internal Examination and IV semester- University Examination)

The students shall select a research project related to current/ emerging trends in Nanoscience and Technology. This should make them familiar with literature survey, studies and development of protocol for nanomaterials, Synthesis, Mechanism, Isolation of product nanomaterials, Standardization of processing parameters, New methods, Research methodologies, Identification of nanomaterial products by analytical, spectral and microscopic methods, and development of applications of nanomaterials. The student will present his/her findings in the form of neatly typed and bound thesis.

Note:

1. Internal and External Examiners will examine this project jointly at the time of practical examination.
2. The students will have to give at least one seminar in each semester related to the latest developments in the field of nanoscience and technology.
3. All project related developments and results (nanoproducts and application tools based on the products) should be submitted at the time of University Examination.
4. The students have to carry out project either at college laboratory or university laboratory or in any R &D laboratory (Public, Private and Government).Institute of national repute across the country under the guidance of a scientist or a faculty member.
5. The student shall submit three copies of the dissertation based on the results of the project work at the end of the Sem. IV. One external examiner and one internal examiner who is the respective supervising teacher of the department shall value the dissertation.
6. The project work carried out during the year, should be presented in power point presentation before University Examiners.

Important Notes:

1. Each theory course is of 60 lectures. Each theory course should be covered in 6 lectures, each of 60 minutes per week,4 periods for lectures and two for tutorials, seminars etc.
2. All theory and practical courses are university courses.
3. Practicals should be carried out on micro scale.
4. Each practical course should be given six hours of laboratory work per week.
5. **Practical batch will consist of not more than 10 students.**
6. Project is compulsory for each student.
7. Post graduate departments should arrange at least one industrial visit.
8. All required chemicals must be made available for practicals and certified journals should be shown to the examiner.