**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**

**M. Tech in NANO TECHNOLOGY**
**Effective from Academic Year 2017- 18 admitted batch**

**COURSE STRUCTURE AND SYLLABUS**

**I Semester**

| Category | Course Title | Int. marks | Ext. marks | L | T | P | C |
|---|---|---|---|---|---|---|---|
| PC-1 | Properties of Nano Structured Materials | 25 | 75 | 4 | 0 | 0 | 4 |
| PC-2 | Synthesis of Nano materials | 25 | 75 | 4 | 0 | 0 | 4 |
| PC-3 | Quantum Mechanics | 25 | 75 | 4 | 0 | 0 | 4 |
| PE-1 | 1. Numerical Methods and Advanced Computing Techniques<br>2. Nano Material Characterization Techniques | 25 | 75 | **3** | 0 | 0 | 3 |
| PE-2 | 1. Nano Bio-Technology, Materials And Devices<br>2. Environmental Nanotechnology | 25 | 75 | **3** | 0 | 0 | 3 |
| OE-1 | ***Open Elective - I** | 25 | 75 | 3 | 0 | 0 | 3 |
| Laboratory I | Synthesis ,Characterization and Simulation Lab | 25 | 75 | 0 | 0 | 3 | 2 |
| Seminar I | Seminar-I | 100 | 0 | 0 | 0 | 3 | 2 |
| **Total** | | **275** | **525** | **21** | **0** | **6** | **25** |

**II Semester**

| Category | Course Title | Int. marks | Ext. marks | L | T | P | C |
|---|---|---|---|---|---|---|---|
| PC-4 | Science and Technology for Thin-films & vacuum | 25 | 75 | 4 | 0 | 0 | 4 |
| PC-5 | Carbon Nanotubes and Applications | 25 | 75 | 4 | 0 | 0 | 4 |
| PC-6 | Nanocomposites – Design and Synthesis | 25 | 75 | 4 | 0 | 0 | 4 |
| PE-3 | 1. Nano Electronics and Photonics<br>2. Nano Sensors and Devices | 25 | 75 | **3** | 0 | 0 | 3 |
| PE4 | 1. Lithographic Techniques<br>2. Nanotechnolgy for Energy Systems | 25 | 75 | **3** | 0 | 0 | 3 |
| OE-2 | ***Open Elective - II** | 25 | 75 | 3 | 0 | 0 | 3 |
| Laboratory II | Fabrication, Characterization and Simulations Lab | 25 | 75 | 0 | 0 | 3 | 2 |
| Seminar II | Seminar-II | 100 | 0 | 0 | 0 | 3 | 2 |
| **Total** | | **275** | **525** | **21** | **0** | **6** | **25** |

**III Semester**

| Course Title | Int. marks | Ext. marks | L | T | P | C |
|---|---|---|---|---|---|---|
| Technical Paper Writing | 100 | 0 | 0 | 3 | 0 | 2 |
| Comprehensive Viva-Voce | 0 | 100 | 0 | 0 | 0 | 4 |
| Project work Review II | 100 | 0 | 0 | 0 | 22 | 8 |
| **Total** | **200** | **100** | 0 | **3** | 22 | **14** |

**IV Semester**

| Course Title | Int. marks | Ext. marks | L | T | P | C |
|---|---|---|---|---|---|---|
| Project work Review III | 100 | 0 | 0 | 0 | 24 | 8 |
| Project Evaluation (Viva-Voce) | 0 | 100 | 0 | 0 | 0 | 16 |
| **Total** | **100** | **100** | **0** | **0** | **24** | **24** |

***Open Elective subjects must be chosen from the list of open electives offered by OTHER departments.**

**# For Project review I, please refer 7.10 in R17 Academic Regulations.**

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**

**I Year -I Sem. M.Tech. (Nano Tech.)**

**PROPERTIES OF NANOSTRUCTURED MATERIALS (PC – 1)**

**Prerequisite:**

1. Familiarization on energy band gap
2. Basics physics & mechanics of solids

**Course Objective:** To bring out the distinct properties like electrical, magnetic, optical, thermal and mechanical properties of nanostructured materials.

**Course Outcomes:**

1. To familiarize about the various properties of nanostructures.
2. To bring out the differences between nano and macro structures.
3. To discuss applications specific properties of nanomaterials.

**Unit – I**

Electronic properties, Energy bands and gaps in semiconductors, Fermi surfaces ,localized particle, donors, acceptors, deep traps, excitons, mobility,size dependent effects, conduction electrons and dimensionality Fermi gas and density of states, semiconducting nanoparticles.

**Unit – II**

Optical properties , Photonic crystals, optical properties of semiconductors, band edge energy, band gap, Core-shell nanomaterials, Quantum dots etc., for size influences of optical properties, optical transitions, absorptions, interband transitions, quantum confinements, Fluorescence/luminescence, photoluminescence/fluorescence, optically excited emission, electroluminescence, Laser emission of quantum dot, Photo fragmentation and columbic explosion, luminescent quantum dots for biological labeling.



**Unit – III**

Magnetic properties, Introduction of magnetic materials, basics of ferromagnetism – ferro magnetic resonance and relaxation, magnetic properties of bulk nanostructures, magnetic clusters, dynamics of nanomagnets, nanopore containment of magnetic particles, nanocarbon ferromagnets, ferrofluids, electron transport in magnetic multilayers.

**Unit – IV**

Thermal properties of nanostructures- thermal conductivity measurements for nanowires, nanotubes, thin films, Nanofluids.

**Unit – V**

Mechanical Properties of nanomaterials, Types of indentation: Oliver & Pharr, Vickers indentation process, Nano Indentation by AFM

**REFERENCE BOOKS:**

1. Introduction to Nano Technology by Charles. P. Poole Jr & Frank J. Owens. Wiley India Pvt. Ltd.
2. Solid State physics by Pillai, Wiley Eastern Ltd.
3. Introduction to solid state physics 7th edition by Kittel. John Wiley & sons (Asia ) Pvt Ltd.
4. Nano Technology and Nano Electronics – Materials, devices and measurement
5. Techniques by WR Fahrner – Springer

6. Encyclopedia of Nano Technology by M. Balakrishna Rao and K. Krishna Reddy, Vol I to X Campus books.
7. Nano Technology - Science, innovation, and opportunity by Lynn E. Foster. Prentice Hall-Pearson education.
8. Hand book of Nano structured materials Vol I & V
9. Encyclopedia of Nano Technology by H.S.Nalwa
10. K K Nanda, Pramana J. Phys., Vol. 72, No. 4, April 2009
11. A.A. Shavtsburg & M.F. Gerald, Chemical Physics Letters 317 2000. 615–618
12. V P Skripov, V P Koverda and V N Skokov, Phys. Status Solid A66, 109 (1981)
13. R Goswami and K Chattopadhyay, Act Mater. 52, 5503 (2004)
14. V. Germain et al. J. Phys. Chem. B, Vol. 107, No. 34, 2003

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**

**I Year -I Sem. M.Tech. (Nano Tech.)**

**SYNTHESIS OF NANOMATERIALS (PC- 2)**

**Prerequisite:**

1. Basic chemistry fundamentals
2. Basic physics fundamentals

**Course Objective:** The course is intended to cover the two groups of synthesis of nanostructure namely top-down and bottom-up approach various synthesis methods, including biological methods, advantages and disadvantages etc,.

**Course Outcomes:**

- The students will be exposes to various structure specific synthesis methods, their advantages etc.
- To know Top-down to Bottom up approach techniques
- To optimize the methods for specific material application

**Unit-I**

Introduction to synthesis of nanostructured materials, Bottom-up approach and Top-down approach with examples.

**Unit-II**

Physical methods: Inert gas condensation, Arc discharge, RF-plasma, electric explosion of wires, ball milling, molecular beam epitaxy, sputtering, evaporation

**Unit- III**

Chemical methods: Nanocrystals by chemical reduction, photochemical synthesis, electrochemical synthesis, co-precipitation method, Nanocrystals of semiconductors and other materials by arrested precipitation, emulsion synthesis, sonochemical routes, microwave assisted synthesis, Template based synthesis of nanomaterials.

**Unit – IV**

Thermolysis route - spray pyrolysis and solvated metal atom dispersion, sol-gel method, solvothermal and hydrothermal routes, solution combustion synthesis, Chemical vapor synthesis and Chemical Vapor Deposition.

**Unit – V**

Biological methods – use of bacteria, fungi, actinomycetes for nano-particle sythesis-magnetotatic bacteria for natural synthesis of magnetic nano-particle, role of plants in nanoparticle synthesis

**REFERENCE BOOKS:**

1. Inorganic Materials Synthesis and Fabrication by J. N. Lalena, D.A. Cleary, E.E. Carpenter, N. F. Dean, John Wiley & Sons Inc.
2. Introduction to Nano Technology by Charles P. Poole Jr and Frank J. Owens. Wiley India Pvt Ltd.
3. The Chemistry of nanomaterials: Synthesis, Properties and Applications, Vol-I by C.N.R. Rao, A. Muller and A.K. Cheetham
4. The Physics of Micro/Nano- Fabrication by Ivor Brodie and Julius J. Muray
5. Encyclopedia of Nanotechnology by M. Balakrishna Rao and K. Krishna Reddy, Vol I to X, Campus books.
6. Encyclopedia of Nanotechnology by H.S. Nalwa
7. Nano: The Essentials – Understanding Nano Scinece and Nanotechnology – by T.Pradeep; Tata Mc.Graw Hill

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**

**M. Tech – I Year – I Sem. (Nano Tech.)**

**QUANTUM MECHANICS (PC -3)**

**Prerequisite:**

1. Basics physics
2. Quantum mechanics
3. Basic chemistry
4. Basic material science

**Course Objective:**

The course is intended to cover, basics concepts of crystallography, quantum mechanics, matter and energy relations, de-Brogile hypothesis, wave function analogies, Schrodinger equation, quantum dot, wires and wells etc.

**Course Outcomes:**

- To know the importance of crystal structures for property evaluation
- Students without quantum mechanics back ground will be able to understand the concept of quantum mechanics and nanotechnology,
- To evaluate nanostructures in quantum mechanical approaches

**Unit-I**

Review of simple harmonic motion, the stretched string equation of motion, standing waves & Fourier waves, the Fourier Transform Problems.

**Unit-II**

Electromagnetic waves, Electromagnetic radiation, Particle mechanics, Theory of Relativity.

**Unit-III**

Introduction-Why quantum mechanics - matter waves-length scales - De-Broglie hypothesis – wave particle duality- Heisenberg's uncertainty principle-Schrodinger wave equation – General postulates of Quantum mechanics- particle in one dimensional box, Bohr's correspondence principle.

**Unit-IV**

Quantum mechanics of electronics: Electron as particle and electron as wave-Time independent Schrodinger equation and boundary condition on the wave function-Analogies between quantum mechanics and classical electromagnetic theory-Probabilistic current density-multiple particle systems.

**Unit-V**

Free and confined electrons: Free electrons-the free electron gas theory of metals-electrons confined to abounded region of space and quantum numbers-electrons confined to atom-the hydrogen atom and the periodic table-quantum dots-wires-wells.

**REFERENCE BOOKS:**

1. Solid state Physics by Kittle {Unit-I,II}
2. P.M. Mathews and K. Venkatesan, "A textbook of Quantum Mechanics", Tata McGraw Hill Publishing Company Ltd {Unit-III}
3. An introduction to solid states electronic devices by Ajay kumar saxena Macmillan India Ltd {Unit-I, II}
4. Quantum Mechanics – Schiff {Unit-III}
5. Quantum Mechanics by B.k. Agarwal and Hariprakash, PHI {Unit-III}

6. Fundamentals of nanoelectronics by George W.Hanson Pearson education {Unit-IV, V}
7. Introduction to Nanotechnology by Charles P. Poole Jr & Frank J. Owens; Wiley India Pvt. Ltd
8. The Feynman lectures on Physics; Vol I to III
9. Quantum mechanics by Brandsen & Joachem
10. J.J. Sakurari, "Modern Quantum Mechanics McGraw Hill, Addison Wesley Longman Inc., USA, 1999
11. Nano Technology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer
12. Nano Technology – science, innovation and opportunity by Lynn E Foster; Prentice Hall - Pearson education.
13. Hand book of Nano structured materials; Vol I to V Bio Ethics Readings and cases by Branch A.Brody & H.Tristram Engelhardt. Jr; Pearson Education
14. Quantum mechanics: - Pawling & Wilson
15. Quantum physics by A. Ghatak
16. Introduction to quantum chemistry by A.K.Chanda
17. Introduction to Quantum Mechanics – Gupta, Kumar, Sharma
18. Quantum Mechanics – Aruthas

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**

**M. Tech – I Year – I Sem. (Nano Tech.)**

**NUMERICAL METHODS AND ADVANCED COMPUTING TECHNIQUES (PE- I)**

**Prerequisite:** Basic engineering mathematics probability & statistics

**Course Objective:**
The course is intended to cover, basics concepts of mathematics like numerical algebra, probability , simulations specially Monte- Carlo simulations which will help in understanding theoretical concepts of Nanotechnology.

**Course Outcome:**
- To know the importance of simulations in nanotechnology.
- Students without mathematics back ground will be able to understand the concept of mathematics.
- To evaluate nanostructured simulations in nanotechnology.

**Unit – I**
Numerics in general: Interpolation, Gauss elimination, Solution by iteration, least square method.

**Unit - II**
Numeric Linear Algebra and differential equations: Matrix Eigen value problems: Introduction, Inclusion of Matrix Eigen values, Tridiognalization and RQ factorization. Methods for first order ODEs, Multi step methods, Higher order ODES

**Unit-III**
Introduction to probability: Probability, Sample space and events- Probability- the axioms of probability, some elementary theorems-conditional probability Baye's theorem Random Variables- Discrete and continuous – distribution- distribution function Distribution Binomial and poison distributions and normal distribution – related properties.

**Unit- IV**
Systems, Models, Simulations and the Monte Carlo Methods: Systems,Models,Simulation and the Monte Carlo Methods, Random number generation, Introduction, Congruential Generators, Statistical Tests of Pseudorandom Numbers, Random variate generation, inverse Transform Method, Composition Method, Acceptance-Rejection Method,

**Unit-V**
Monte Carlo integration and Variance reduction techniques: Introduction, Monte Carlo Integration, The Hit or Miss Monte Carlo Method, The Sample-Mean Monte Carlo Method, Efficiency of Monte Carlo Method, Integration in Presence of Noise,

**TEXT BOOKS:**
1. Advanced engineering mathematics, by Erwin Kreyszig, wiley publications
2. Probability and statistics, scham series, Arnold o. allen, academic press
3. Probability and statistics, Arnold o. allen, academic press
4. Probability and statistics for engineers, miller and john e. freund, prentice hall of india
5. A primer for the monte carlo method, Ilya M. Sobol' CRC Press
6. Simulation and monte carlo method by reuven y. rubisten
7. The monte carlo method, popular lectures in mathematics by sobol.i.m

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**

**M. Tech – I Year – II Sem. (Nano Tech.)**

**NANO MATERIAL CHARACTERIZATION TECHNIQUES (PE – I)**

**Prerequisite:**

1. Basic band gap, energy systems
2. Mechanics of solids, metallurgy and materials science

**Course Objectives:**

To familiarize students with material characterization techniques and its importance and to get exposure with various techniques of characterization and interpretation of results including standards etc.,

**Course Outcomes:**

- To bring out the importance of material characterization and various methods
- To bring out electrical, thermal and other characterization techniques.
- To familiarize about various equipment.

**Unit – I**

Compositional and structural Characterization techniques: X-ray Photoelectron Spectroscopy (XPS), Energy Dispersive X-ray analysis (EDAX), Principles and applications of X-ray diffraction; electron diffraction, Electron probe microanalysis (EPMA), Ion beam techniques: SIMS & RBS. Case studies.

**Unit – II**

Advanced Microscopy Techniques for Nano materials Characterization High resolution microscopy; Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Atomic force microscopy (AFM), scanning tunneling microscopy (STM).

**Unit – III**

Spectroscopic techniques: UV- Visible Spectroscopy, Photo-luminescence Spectroscopy, Mossbauer spectroscopy, Fourier Transform infrared (FTIR) spectroscopy, Raman spectroscopy techniques: micro Raman and laser Raman. Examples with nano materials.

**Unit – IV**

Nano materials Electrical characterization techniques: Measurement of resistivity by 4-prob method, Hall measurement, electron beam induced current measurement (EBIC).

**Unit-V**

Thermal and Magnetic characterization: Thermal analysis, Vibrating Sample Magnetometer, SQUID magnetometer

**REFERENCE BOOKS:**

1. Nano: The Essentials -Understanding Nano Science and Nanotechnology by T.Pradeep, Tata Mc. Graw Hill
2. Introduction to Nano Technology by Charles. P. Poole Jr and Frank J. Owens, Wiley India Pvt Ltd.
3. A practical approach to X-Ray diffraction analysis by C. Suryanarayana
4. Electron Microscopy and analysis by P.J. Goodhew and F.J. Humpreys
5. Scanning electron microscopy and x-ray microanalysis by J.I. Goldstein
6. Characterization of nanostructured materials by Z.L. Wang
7. Modern Raman Spectroscopy: A practical approach by E. Smith and G.Dent

8. Principles of Instrumental analysis by D.A. Skoog, F.J. Hollen and T.A. Niemann
9. Atomic and Molecular Spectroscopy: Basic Aspects and Applications by S.Svanberg
10. Nanotechnology: Principles and Practices – Sulabha K. Kulkarni – Capital Publishing Company
11. Specimen preparation for Transmission Electron microscopy by John & Bravmno et al, published by MRS
12. Photoelectron spectroscopy by JHD Eland, Butterworth & Co. publishers, 2nd education.
13. Encyclopedia of Nanotechnology by H. S. Nalwa

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**

**M. Tech – I Year – I Sem. (Nano Tech.)**

**NANO BIO-TECHNOLOGY-MATERIALS AND DEVICES (PE – II)**

**Prerequisite:**

1. Fundamentals of Biotechnology
2. Basic biological Systems

**Course Objectives:**

The course is intended to cover fundamental terms and basics of biotechnology and building blocks; biological nanostructures, biosensors and biomedical applications of nanotechnology, nanodrugs and drug delivery systems.

**Course Outcomes:**

- To familiarize student with biological systems, materials, sensors and building blocks.
- To familiarize about biomedical applications, nanodrugs, molecular modeling of drugs and drugs delivery systems

**Unit–I**

Fundamentals terms in biotechnology, Biological building blocks: Sizes of building blocks and Nanostructures, nucleic acids, genetic code and protein synthesis, DNA double nano wires, protein nanoparticles and polypeptide nanowires

**Unit-II**

Biological Nanostructures: Bio-mimitics with examples, Bio mineralization, Bio compatible Bio sensors, Examples of proteins, micelles, vesicles, bilayers, and Multilayer films, application of bio-nanotechnology: bio nano machines, molecular modeling.

**Unit – III**

Nano bio-sensors and biomedical applications, organic semiconductors, biological neurons and their functions, bio-chemical and quantum mechanical computers: DNA computers, parallel processing, Bit and 'Q' bit, Quantum parallelism.

**Unit –IV**

Biomolecular sensing for cancer diagnostics using carbon nanotubes, nano devices in biomedical applications, nanoscale polymer fabrication for biomedical application, nanotechnology in cancer drug therapy: A biocomputational approach

**Unit –V**

Introduction to drugs, Classification of drugs, Encapsulation of drugs, Nano drug delivery: Conventional drug delivery, targeted drug delivery, chemistry of drug delivery, role of nanotechnology in drug delivery, bionanoimaging, magnetic nanoparticles for MR imaging, Magnetic hyperthermia in cancer treatment

**REFERENCE BOOKS:**

1. Bio Nano Technology by Good Sell, Wiley Liss
2. Nanotechnology by John F. Mongillo
3. Introduction to Nanotechnology by Charles. P. Poole Jr and Frank J. Owens, Wiley India Pvt Ltd.
4. Nano Technology, A gentle introduction to the next big idea by Mark Ranter and Daniel Ranter, Pearson education

5. Nanotechnology – science, innovation and opportunity by Lynn E Foster, Prentice Hall-Pearson education.
6. Biological and Biomedical nanotechnology by Abraham P. Lee and L. James Lee
7. Biomedical Applications of Nanotechnology by Vinod Labhasetwar and Diandra L. Leslie - Pelecky
8. Biomedical Nanostructures by Kenneth E. Gonsalves, Craig R. Halberstadt, Cato T. Laurencin, Lakshmi S. Nair
9. Sensors, Nanoscience, Biomedical, Engineering and Instruments by Richord C.Dorf
10. Encyclopedia of Nanotechnology by H.S. Nalwa
11. Encyclopedia of Nanotechnology by M. Balakrishna Rao and K.Krishna Reddy (Vol I to X), Campus books.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**

**M. Tech – I Year – I Sem. (Nano Tech.)**

**ENVIRONMENTAL NANOTECHNOLOGY (PE – II)**

**Prerequisite:**

1. Basics of organic chemistry
2. Waste water treatment

**Course Objective:**

This course covers the importance of all different aspects and effects of environmental nanotechnology.

**Course Outcomes:**

- To know about nanostructured catalysts such as $TiO_2$ nanoparticles for water purification.
- To learn about nanoparticles for treatment of chlorinated organic contaminants.
- To have knowledge about nanoparticles for treatment of arsenic, environmental risks of nanomaterials

**Unit-I:**

**Introduction:** Introduction to Environmental Applications, Implications of Nanotechnology & Research needs

**Unit-II:**

**Nanostructured Catalysts $TiO_2$ Nanoparticles for Water purification:** $TiO_2$ as a semiconductor photocatalyst, Photo catalytic mechanism,general pathways & kinetics, Intrinsic Photocatalytic activity, Reaction variables, Photocatalytic Degradation of Specific Waterborne pollutants.

**Unit-III:**

**Nanoparticles for treatment of Chlorinated Organic Contaminants:** Introduction, Overview of Chlorinated Organic Solvents, Biodegradation of Chlorinated Organic Solvents, Nanoscale zero-valene iron (NZVI), Application of other Nanoscale metallic particles in chlorinated organic compound degradation.

**Unit-IV:**

**Nanoparticles for treatment of Arsenic:** Introduction, Environmental Chemistry of Arsenic, Treatment of Arsenic using Nanocrystalline $TiO_2$, Treatment of Arsenic using nanoparticles other than $TiO_2$.

**Unit-V:**

**Nanomembranes:** Nanomembranes in Drinking water treatment, Nanomembranes in Sea desalination.

**Environmental Risks of Nanomaterials:** Routes of NMS into the Water environment, Hazardous effects of NMs on Human and Animal Health,Risk Management**.**

**TEXT BOOK:**

1. Nanotechnologies For Water Environment Applications American Society of Civil Engineers (ASCE) Publications by Tian C. Zhang, Zhiqiang Hu, Rao Y. Surampalli, R.D. Tyagi, Keith C.K. Lai and Irene Mc. Lao

**REFERENCE BOOK:**

2. Nanotechnology in Water Purification Applications Caister Academic Press by T. Eugene, Michele de Kwaadsteniet, Marelize Botes and J. Manuel Lopez-Romero.

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**

**M. Tech – I Year – I Sem. (Nano Tech.)**

**SYNTHESIS, CHARACTERIZATION AND SIMULATION LAB**

**LAB - I**

**Unit - I:**
Methods for the synthesis of nanomaterials and thin film technology (CVD method, Spin Coating, Spray Pyrolysis and Sputtering)

**Unit - II:**
Nano – material Preparation by Chemical methods

**Unit - III:**
Synthesis of oxide Nanostructures / nano composites by Sol-gel Process

**Unit - IV:**
**ARGUS LAB:**

1. Construction of fullerene & its energy calculations
2. Construction of Bucky balls (C20, C40, C60, C80, C100, C120)
3. Construction of Carbon nanotubes
4. Energy minimization of lysozyme and its mutant
5. Energy minimization of chymotrypsin and its mutant
6. Energy minimization of enzymes involved in Neurological science

**Unit - V:**
**MOSES 1.2**

1. Study single electron transistor using MOSES 1.2 simulator
2. Simulation of I – V characteristics for a single junction circuit with a single quantum dot using MOSES 1.2 simulator



**REFERENCE BOOKS:**

1. Advanced catalysis and Nano structured material by WR Moser.
2. Introduction to Nano Technology by Charles. P.Poole Jr and Frank J. Owens Wiley India Pvt Ltd.
3. Encyclopedia of Nanotechnology by H.S. Nalwa
4. Nano: The Essentials – Understanding Nano Science and Nanotechnology – by T. Pradeep; Tata McGraw Hill