# Shivaji University, Kolhapur

**M. Sc. in Nanoscience and Technology, Part I**
**under CBCS Pattern (2021-22)**

To be implemented from the academic year 2021-22
(June 2021) onwards.

**Shivaji University, Kolhapur,**
**School of Nanoscience and Technology,**
**M. Sc. in Nanoscience and Technology, Programme, Part-I**
**under CBCS Pattern (2021-22)**

## M. Sc. in Nanoscience and Technology, Part I, Semester–I

| Sr. No. | Paper Code | Title of the Paper |
|---|---|---|
| 1 | CP-1 | Semiconductor Physics |
| 2 | CP-2 | Carbaneous Materials |
| 3 | CP-3 | Functional Nanomaterials |
| 4 | CP-4 | Coating Technology, Nanocoatings and Applications |
| 5 | CP-5 | Nanobiotechnology |
| 6 | CP-6 | Quantum Mechanics at Nanoscale |
| 7 | CP-1- Lab. | Laboratory Course-I (Semiconductor Physics -Lab.) |
| 8 | CP-2-Lab. | Laboratory Course-II (Carbaneous Materials. -Lab.) |
| 9 | CP-3 & CP-4 –Lab. | Laboratory Course-III (Functional Nanomaterials & Nanocoatings and Applications -Lab.) |
| 10 | CP-5-Lab. | Laboratory Course-IV (Nanobiotechnology -Lab.) |

## M. Sc. in Nanoscience and Technology, Part I, Semester–II

| Sr. No. | Paper Code | Title of the Paper |
|---|---|---|
| 1 | CP-7 | Solid State Electronic Devices |
| 2 | CP-8 | Energy Conversion and Storage Devices |
| 3 | CP-9 | Fundamentals of Nanocatalysis and Applications |
| 4 | CP-10 | Nanomagnetism and Spintronics |
| 5 | CP-11 | Biomedical Applications of Nanobiotechnology |
| 6 | CP-12 | Statistical Mechanics and Nanothermodynamics |
| 7 | CP-7- Lab. | Laboratory Course-I (Solid State Electronic Devices -Lab.) |
| 8 | CP-8-Lab. | Laboratory Course-II (Energy Conversion and Storage Devices –Lab.) |
| 9 | CP-9–Lab. | Laboratory Course-III (Fundamentals of Nanocatalysis and Applications -Lab.) |
| 10 | CP-11-Lab. | Laboratory Course-IV (Biomedical Applications of Nanobiotechnology -Lab.) |

**M. Sc. in Nanoscience and Technology,**

**Part I, Semester–I**

**Title of the paper: CP-1-Semiconductor Physics**

| Sr. No. | Topics | No. of Lectures |
|---|---|---|
| **Unit I** | **Energy Bands and Charge Carriers in Semiconductors:** Bonding forces and energy bands in solids, Direct and Indirect semiconductors, variation of energy bands with alloy composition, Charge carriers in semiconductors: electrons and holes, effective mass, intrinsic and extrinsic materials, electrons and holes in quantum wells, The Fermi level, carrier concentration at equilibrium, temperature dependence, space charge neutrality, conductivity and mobility, Drift and resistance, effects of temperature and doping on mobility, High field effects. | **15** |
| **Unit II** | **Excess Carriers in Semiconductors:** Optical absorption, Luminescence, Direct recombination of electrons and holes, Indirect recombination and trapping, steady state carrier generation and Quasi Fermi levels, Diffusion processes, Diffusion and Drift of carriers, built in fields, The continuity equation, steady state carrier injection, diffusion length, The Haynes-Shockley experiment. | **15** |
| **Unit III** | **Junctions-I:** **Fabrication of pn junctions;** Thermal oxidation, diffusion, Rapid thermal processing, Ion implantation, CVD, Photolithography, etching, metallization, The contact potential, Space charge at a junction, qualitative description of current flow at a junction, Carrier injection, | **15** |

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| | reverse bias breakdown, Zener and Avalanche breakdown | |
| **Unit IV** | **Junctions-II:**<br>Capacitance of PN junctions, the Varactor diode, effects of contact potential on carrier injection, recombination and generation in the transition region, ohmic losses, graded junctions, Shottky barriers, rectifying contacts, ohmic contacts, heterojunctions, AlGaAs-GaAs heterojunction. | **15** |

**Reference Books:**

1.Solid state electronic devices by B. G. Streetman.

2.Physics of semiconductor devices by S. M. Sze.

3.Solid State and Semiconductor Physics by McKelvey.

4.Principles of Electronic Materials and Devices by S. O. Kasap

**M. Sc. in Nanoscience and Technology,**

**Part I, Semester–I**

**Title of the paper: Laboratory Course-I**

| Sr. No. | Name of the Experiment |
|---|---|
| 1. | Resistivity of thin film by two probe method |
| 2. | PN junction diode characteristics |
| 3. | Estimation of bandgap of semiconductor |
| 4. | Modeling and simulation of Carrier concentrations in semiconductors |
| 5. | Estimation of TEP of a semiconductor |
| 6. | Modeling and simulation of mobility of charge carriers |
| 7. | Excess electron and hole concentrations |
| 8. | Modeling and simulation of Fermi level in semiconductors |
| 9. | Photoluminescence in semiconductors |
| 10. | Hall effect |

**M. Sc. in Nanoscience and Technology,**

**Part I, Semester–I**

**Title of the paper: CP-2- Carbaneous Materials**

| Sr. No. | Topics | No. of Lectures |
|---|---|---|
| **Unit I** | **Graphene:** Introduction of graphene: Definition and structure of graphene, Types of graphene: stacking AA, BB, AB dispersion relation, Single layer, Bi-layer, Few layer graphene; **Properties of graphene:** Optical: thickness dependency, optical conductivity, electric field tunable transparency, plasmons and polaritons, carrier multiplication; Electrical: Boltzmann equation, ambipolar conduction, density of states and doping (electrostatic and chemical), quantum hall effect, Klein tunneling, diamagnetism, magnetoresistance and spin current; thermal conductivity; Characterization of graphene: Transmission electron microscopy (TEM), Scanning tunneling microscopy (STM), Raman Spectroscopy, NMR spectroscopy, Electrical measurements: electric field effect, temperature dependent resistivity measurement. | **15** |
| **Unit II** | **Synthesis Methods of graphene:** Epitaxial growth of graphene on Silicon carbide, Chemical vapour deposition (CVD) growth of graphene films, Chemically derived graphene, Synthesis of graphene oxide: Hummer's method, Modified Hummer's method, Reduction of graphene oxide: Chemical methods and Physical methods, Electrochemical exfoliation, Nanotube slicing from solid state carbon sources. | **17** |

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| | **Applications of graphene:** Graphene in the energy application: Li-ion batteries, Supercapacitors, Photovoltaic, Radio-frequency transistor, Photodetector, Modulator, Mode locked lasers; Other applications of graphene: Anti-corrosion coating, Antibacterial coating, catalyst, Sensors, Transparent Conductors. | |
| **Unit III** | **Carbon Nanotubes:** Introduction of Carbon Nanotube (CNT): Definition of CNT, Bonding of carbon atoms, SP3, SP2, Deformed SP2, Structure of Carbon Nanotubes, Chiral Vector; Types of Carbon nanotubes: Armchair, Zig-Zag and Chiral; Properties of Carbon<br>Nanotubes: Electronic, Optical and Optoelectronic, Mechanical, Chemical and Electrochemical, Thermal and Thermoelectric; Opening, wetting and filling, doping, intercalation. Characterization of carbon nanotubes: Raman spectroscopy, NMR spectroscopy, AFM etc. | **14** |
| **Unit IV** | **Synthesis Methods and Growth Mechanisms of Carbon Nanotubes:** High temperature methods: Arc discharge, General technical features of the production process, Growth Mechanism, Laser Ablation of Graphite; Low temperature method: Chemical Vapour<br>deposition (CVD) process, Vapour liquid solid model, Catalytic role.<br>**Purification and functionalization:** Methods of Purification, Methods of Functionalization (Chemical and Physical), Advantage of purification and functionalization, Separation of carbon nanotubes based on chirality: semiconducting, metallic; **Applications of Carbon nanotubes:** Field emission, Li-ion battery, Supercapacitor, Sensors, Solar cell, CNT-polymer composite and avionics EM shielding. | **14** |

**Reference Books:**


1. Graphene: Carbon in Two Dimensions, by Mikhail. Katsnelson (http://www.amazon.com/Graphene-Dimensions-Mikhail-I-Katsnelson/dp/0521195403)
2. Physics of Graphene, Editors: Aoki, Hideo, S. Dresselhaus, Mildred (Eds.) http://www.springer.com/in/book/9783319026329
3. Graphene:Synthesis, Properties, and Phenomena, by C. N. R. Rao (Editor), Ajay K. Sood (Editor) http://www.amazon.com/Graphene-Synthesis-Properties-Phenomena-Rao/dp/3527332588/ref=pd_sim_b_2?ie=UTF8&refRID=1BE9W35KXA6TXMMMXVEP
4. Graphene Nanoelectronics, Metrology, Synthesis, Properties and Applications, Editors: Raza, Hassan (Ed.) http://www.springer.com/in/book/9783642204678
5. Graphene Nanoelectronics: From Materials to Circuits, Editors: Murali, Raghu (Ed.) http://www.springer.com/in/book/9781461405474
6. Carbon Nanotube and Graphene Device Physics, by H. S. Philip Wong (Author), Deji Akinwande (Author) http://www.amazon.com/Carbon-Nanotube-Graphene-Device-
7. Carbon Nanotube Electronics (Integrated Circuitsand Systems) by AliJavey (Editor), Jing Kong (Editor), http://www.amazon.com/Nanotube-Electronics-Integrated-Circuits-Systems/dp/0387368337%3FSubscriptionId%3D1VXT0MZ5J2QQ5RY3VV02%26tag%3Dgrapheneinfo-20%26linkCode%3Dxm2%26camp%3D2025%26creative%3D165953%26creativeASIN%3D0387368337
8. Polymer-Graphene Nanocomposites, Editor(s): Vikas Mittal http://pubs.rsc.org/en/content/ebook/978-1-84973-567-4#!divbookcontent
9. Physics and Chemistry of Graphene: Graphene to Nanographene,Toshiaki Enoki,Tsuneya Ando http://www.crcpress.com/product/isbn/9789814241489

**M. Sc. in Nanoscience and Technology,**

**Part I, Semester–I**

**Title of the paper: Laboratory Course-II**

| Sr. No. | Name of the Experiment |
|---|---|
| **1.** | Raman spectroscopy of graphene. |
| **2.** | Raman spectroscopy carbon nanotubes. |
| **3.** | Synthesize the graphene oxide by Modified Hummers Method. |
| **4.** | Synthesis of reduced graphene oxide by chemical reduction of graphene oxide. |
| **5.** | Simulation of Crystalline Solar Cells |
| **6.** | Simulation Study of Carbon Nanotubes (CNTs) |
| **7.** | Functionalization of carbon nanotubes. |
| **8.** | Contact angle measurements. |

**M. Sc. in Nanoscience and Technology,**

**Part I, Semester–I**

**CP-3-Functional Nanomaterials**

| Sr. No. | Topics | No. of Lectures |
|---|---|---|
| **Unit I** | **Semiconductor quantum dots and metal organic frameworks**<br>**Semiconductor quantum dots-** Introduction, Magic size cluster (shape and composition control), Basic properties of nanocrystals, Multishell semiconductor nanocrystals, Applications of quantum dots<br>**Metal Organic Frameworks (MOF)-** Introduction, advantages, disadvantages, methods of synthesis, Structural originality of MOFs, properties, Applications | **15** |
| **Unit II** | **Nanotubes, nanowires and nanofibers**<br>**$TiO_2$ nanotubes**<br>Introduction, Properties of $TiO_2$ nanotube arrays: Structural, Elemental, Mechanical, Optical, and Electrical, Applications, Inorganic nanowires<br>**Nanofibers**<br>Introduction, Electrospinnnig process, Nanofiber yarns and fabrics, Applications of electrospun fibers, Nanofibers for Tissue Engineering Scaffolds, Nanofibers for Chemical/Bio Protective Membranes, Nanocomposite Fibers for Structural Applications | **17** |
| **Unit III** | **Carbon fibers and nanotubes, Inorganic nanofibers and Nanocomposites** | **18** |

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| | **Carbon fibers and nanotubes**<br>Types of fibers, whiskers and nanotubes, Applications<br>**Organic polymer nanocomposites**<br>Introduction, Polymerization, Interfacial area, Nanofilled composites design and applications, Enhanced polymer nanocomposites<br>**Metal and Ceramic nanocomposites**<br>Inorganic nanofibers-silicon carbide, boron nitride nanotubes and fibers, Cermets, Concrete- carbon fiber and nanotube-reinforced concrete, nanocomposite cements | |
| **Unit IV** | **Natural nanocomposites**<br>Skin of the sea cucumber, hard natural nanocomposites<br>**Clay nanocomposite materials**<br>Polypropylene-clay nanocomposite, Montmorillonite clay nanocomposite, Halloysite nanotube clay nanocomposite | **10** |

**Reference Books:**


1) Semiconductor Nanocrystal, Quantum Dots: Synthesis, Assembly, Spectroscopy and Applications by Andrey L. Rogach (Ed.), Springer Publisher
2) $TiO_2$ Nanotube Arrays: Synthesis, Properties, and Applications by Craig A. Grimes and Gopal K. Mor, Springer Publisher
2) Nanotubes and Nanofibers; Advanced Materials Series, Series Editor: Yury Gogotsi, Drexel University, Philadelphia, Pennsylvania, USA, Nanotubes and Nanofibers by Yury Gogotsi
3) Hybrid porous solids: past, present, future by Gerard Ferey, Chemical Society Reviews, 37 (2008) 191-214. DOI: 10.1039/b618320b
4) Introduction to Nanoscience and Nanotechnology by Garbor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Boca Raton, FL, USA, 2009.
5) Nanotubes and Nanowires, CNR Rao and Govindraj, RSC Publishers

**M. Sc. in Nanoscience and Technology,**

**Part I, Semester–I**

**Title of the paper: Laboratory Course-III**

| Sr. No. | Name of the Experiment |
|---|---|
| 1 | Synthesis of CdSe-CdS core shell QD by hot injection method |
| 2 | Synthesis of TiO2 nanotubes array by electrochemical anodization |
| 3 | Electrodeposition of MnO2 by potentiodynamic method |
| 4 | Deposition of PbS thin film by SILAR technique |
| 5 | Preparation of TiO2 thin film by spray pyrolysis technique |
| 6 | Synthesis of ZnO nanorod thin film using microwave method |
| 7 | Synthesis of TiO2 nanofibers by electrospinning technique |
| 8 | Mechanical exfoliation of graphite into graphene |

**M. Sc. in Nanoscience and Technology,**

**Part I, Semester–I**

**CP-4-Coating Technology, Nanocoatings and Applications**

| Sr. No. | Topics | No. of Lectures |
|---|---|---|
| **Unit I** | **Introduction to Coating Technology:** Definition of coatings, different types of conventional coatings (examples and function), coating formulations, Factors influencing formulation (viscosity, rheology and types). Role of surface chemistry in coatings. Terminology involved with conventional coating technology and their significance with examples. (solvent/carrier, binders, additives, fillers and solid contents).<br>**Introduction to Nanocoatings:** Definition, difference between conventional coatings and nanocoatings. Functional coatings, types and significance. Role of solvent, surface passivation) in nanoformulation. Effect of particle size and shape in nanocoatings (stabilizers).<br>Smart coatings definition, applications with example.<br>**Techniques and Tools for Nanocoating:** Sol-gel, dip coating, spin coating, spray pyrolysis and their types, chemical vapor deposition (CVD), SILAR, plasma and types (pulsed plasma nanocoating), electrodeposition (anodization), electroplating, electrospinning, hydrothermal, solvothermal. | **18** |
| **Unit II** | **Functional Nanocoatings I:**<br>Lotus effect, discovery and origin of self cleaning surface coatings. Contact angle, theory of superhydrophilic, | **18** |

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| | hydrophilic, hydrophobic and superhydrophobic (Young's equation, Wenzel's and Cassie-Baxter equation) Self cleaning glass (solar panel, energy saving buildings, slef cleaning/dirt free fabrics) Anti-microbial Nanocoatings: Introduction, Nano-Coating use Against SARS Virus, Application of Ag Nanoparticles as Antibacterial Coating, Using TiO2 Nano-Particles to Decrease Environmental Contaminations, Anti-fouling Nanocoatings: Introduction, Applications of Anti-fouling Superhydrophobic Nanocoatings: Introduction, Superhydrophobic surface, self cleaning surfaces, methods for surface roughening: Nakajima, Erbil and Patankar approaches. Applications of hydrophobic nanocoatings companies and products.<br>UV-resistant Nanocoatings: Introduction, Necessity of UV-resistant nanocoatings, Types of UV-resistance Nanocoatings, mechanism of protection. Applications<br>Conductive Nanocoatings: Introduction, Necessity of Conductive Nanocoatings, Conductivity fundamentals, Coating Build-Up, Control of optoelectronic properties, Methods of Coatings Characterization, Properties of Coatings, Applications of conductive nanocoatings in biosensors. | |
| **Unit III** | **Functional Nanocoatings II and III:**<br>Anti-corrosion Nanocoatings: Introduction, Principle of prevention & protection of Corrosion, Advantages and disadvantages of Anti-corrosion Nanocoatings, Advanced protective coatings for aeronautical applications<br>Thermal barrier and flame retardant Nanocoatings: Introduction, Applications of Thermal barrier and flame retardant Nanocoatings. Role of gas barrier coating in flame retardant and anti-corrosion. | **14** |

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| **Unit IV** | **Smart Nanocoatings:** Self cleaning surfaces like light saving glass buildings. Self healing nanocoating. Superhydrophobic-anti dust nanocoatings. Optoelectronics nanocoatings.<br>**Hard and Soft Nanocoatings:** Anti-finger print, anti-abrasion, anti-skratch, anti-static nanocoatings. | **10** |

**Reference Books:**


1. COATINGS TECHNOLOGY FUNDAMENTALS, TESTING, AND PROCESSING TECHNIQUES, Chapter 1: Edited by Arthur A. Tracton, CRC Press, Taylor & Francis Group.
2. Nanocoatings: Principles and practice By steven abbott and Nigel Holmes
3. Bioinspired Intelligent Nanostructured Interfacial Materials, Lei Jiang and Lin Feng
4. PAINT AND SURFACE COATINGS Theory and Practice, Second edition: Editors: R LAMBOURNE and T A STRIVENS, Woodhead Publishing Limited, Cambridge, England.

## M. Sc. in Nanoscience and Technology,
## Part I, Semester–I

### CP-5- Nanobiotechnology

| Sr. No. | Topics | No. of Lectures |
|---|---|---|
| **Unit I** | **Biological synthesis of nanomaterials and their applications:** Biological synthesis of nanoparticles using bacteria, fungi, plants, purified enzymes, biological templates and S layer. Silver nanoparticles, gold nanoparticles, cerium oxide nanoparticles, titanium oxide and zinc oxide nanoparticles. Biological applications of inorganic nanoparticles.<br>**Introduction to biological nanoparticles and their applications:** Exosomes, lipoproteins, ferritin, magnetite viruses. Biological nanomotors and Machines, mechanisms of biological machines, protein assemblies: muscle myosin, kinesin, nerve, ATPase, bacteriorhopsin, Hemoglobin dynein, cilia. Bacterial flagella: structure and function; nanomotor. Ion channels: nanopores of high specificity.<br>**Bioinspired nanomaterials:** DNA and peptide based. Interaction between biomolecules and nanoparticle surfaces. | **15** |
| **Unit II** | **Nanomaterial- Biomolecule interactions and Biosensors:** Protein-lipids-RNA and DNA, protein targeting, Small molecule/nanomaterial-protein interactions, Nanomaterial– cell interactions, Manifestations of surface modification (Polyvalency). Surface modified nanoparticles, MEMS/NEMS based on nanomaterials, Peptide/DNA coupled nanomaterial, Metal / metal oxide nanoparticles (antibacterial / antifungal / antiviral), Anisotropic and magnetic nanoparticles | **15** |

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| | (Hyperthermia) Nanonephrology, Nanosystems in Inflammation, Targeting Macrophages to Control Inflammation, Tissue Regeneration, Growth and Repair, Tissue Bioengineering; Future Understanding for Treatment.<br>Biosensor and nanobiosensor, basic concepts, characterization, perception, Enzyme–metal NP hybrids for biosensing and for the generation of nanostructures, Biomolecule–semiconductor NPs for biosensing, Different types of nanobiosensors; CNT biosensor, DNA nanosensor, Nanowire biosensor, application of nanodiagnostics.Nanobiosensors for medical diagnostics. Nanoprobes for analytical applications | |
| **Unit III** | **Fundamentals of Animal tissue culture:** Introduction to animal tissue/cell culture and lab facility, Definition, principle and significance of tissue culture. Maintenance of sterility, use of antibiotics, Logic of formulation of tissue culture media: natural, synthetic media, and sera. Sterilization of cell culture media and reagents. Introduction to the balance salt solutions and simple growth medium. Role of carbon dioxide in animal cell culture.<br>**Primary culture:** Behavior of cells, properties, utility with different examples. Explant culture. Suspension culture. **Concept of Cell lines, Normal and established cell lines:** Their characteristic features and utility, Characteristics of cells in culture. Contact inhibition, anchorage (in) dependence, cell-cell communication, Cell senescence. | **15** |
| **Unit IV** | **Nanotechnology and its application in food industry:** Nanotechnology and food packaging, natural biopolymers, advantages of nanomaterials in food packaging applications, outstanding issues, risks and regulations, public perception.<br>Nanotechnology in Agriculture, Precision farming, Smart delivery system, Insecticides using nanotechnology, Potential of nanofertilizers. | **15** |

**Reference Books:**


1. Principles and techniques of Biochemistry and Molecular biology, 7th Edition, Keith Wilson and John Walker. Cambridge University Press, 2010
2. Analytical Techniques in Biochemistry and Molecular Biology, Rajan Katoch, Springer, 2011
3. Basic Cell Culture Protocols, Editors: Helgason, Cheryl D., Miller, Cindy L, Springer 2005
4. Proteomic and Metabolomic Approaches to Biomarker Discovery, Haleem J Issaq, Academic press. 2013
5. Challa Kumar- Biological and pharmaceutical Nanomaterials, Wiley-VCH Verlag GmbH & Co. KGaA.
6. Cato T. Laurencin and Lakshmi S. Nair, Nanotechnology and Tissue Engineering The Scaffold, CRC Press taylor & Francis Group.
7. Peter X Ma, Scaffolds for tissue fabrication, materials today Volume 7, Issue 5, May 2004, Pages 30–40
8. K. K. Jain, Nano Biotechnology, Horizions Biosciences, 2006
9. Martin C. Woodle, Patrick Y. Lu Nanoparticles deliver RNAi therapy, materials today, Volume 8, Issue 8, Supplement, August 2005, Pages 34–41
10. C. Kumar, Nanomaterials for medical diagnosis and therapy, Wiley –VCH, 2007, USA
11. Chemical Sensors and Biosensors; Brian, R Eggins; Wiley; New York, Chichester; 2002.
12. Biosensors and modern biospecific analytical techniques, Wilson & Wilson's Comprehensive Analytical Chemistry; Ed. L Gorton; Elsevier, Amsterdam, London; 2005.
13. The Immunoassay Handbook; Ed. David Wild; 3rd ed.; Amsterdam: Elsevier; 2005.
14. Electrochemical Methods: Fundamentals and Applications; Allen J Bard and Larry R Faulkner; Wiley, New York, Chichester: 2nd ed.; 2001.
15. 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
16. Biosensors: A Practical Approach, J. Cooper & C. Tass, Oxford University Press, 2004.
17. Nanomaterials for Biosensors, Cs. Kumar, Wiley – VCH, 2007.
18. Smart Biosensor Technology, G.K. Knoff, A.S. Bassi, CRC Press, 2006.

19. Bernard R. Glick and Jack J. Pasternak (2002). Molecular Biotechnology, Panima Publishing House, New Delhi. PG & Research Department of Biotechnology, National College (Autonomous), Tiruchirappalli – 620001. 18
20. Garrison C, Fathman F and Fitch W. (1982). Isolation- Characterization and utilization of T – Lymphocyte clones, Academic Press
21. Goldsby R. A. Kindt T.J, Osborne B. A and Kuby J. (2003). Immunology, W.H. Freeman and company.
22. Griffiths A. J, Miller J.H, Suzuki D.T, Lewontin R.C and Gelbart W.M. (2000). An introduction to Genetic analysis, W. H.Freeman and Company.
23. Masters J.R.W. (2000), Animal Cell culture, Oxford University Press.
24. Puher A. (1993). Genetic Engineering of animals (Ed.), VCH Publishers-WeinheimFRG.
25. Ranga M.M. (2003). Animal Biotechnology.
26. Springer T. A. (1985), Hybridoma Technology in Biosciences and Medicine, Plenum Press, New York.
27. Watson J.D, Gilman M, Witknowski J and Zoller M. (1992). Recombinant DNA, Scientific American Books, New York.
28. Watson J.D, Hopkins N.H, Roberts J.W. Steitz J. A and Weiner A.M. (2002). Molecular Biology of gene, Benjamin / Cummings.

## M. Sc. in Nanoscience and Technology,
## Part I, Semester–I

**Title of the paper: Laboratory Course-IV**

| Sr. No. | Name of the Experiment |
|---|---|
| 1 | Preparation of nanoparticles using biological source |
| 2 | Preparation of nanoparticles using bacterial cells, its extracellular proteins and characterization |
| 3 | Preparation of nanoparticles using fungi, Its extracellular proteins and characterization |
| 4 | Preparation of various metal nanoparticles for the study of their biological activity |
| 5 | Estimation of antibacterial activity of metal nanoparticles |
| 6 | Preparation of nanoparticles using plant extract and its characterization |
| 7 | Estimation of antifungal activity of metal nanoparticles |
| 8 | Preparation of glasswares, plasticwares, media and fine chemicals for animal cell cultures |
| 9 | Culturing, maintenance and passaging of stock of animal cell cultures |
| 10 | Synthesis of gold nanoparticles and its assembly/Conjugation with biomolecules i.e. BSA |
| 11 | SDS PAGE gel shift assay for study of nanoparticle-biomolecule assembly |

**Reference Books:**

1. Charles P. Poole Jr. and Franks. J. Qwens (2003) Introduction to Nanotechnology, Wiley

2. Ehud Gazit (2007) Plenty of Room for Biology at the Bottom: An Introduction to Bionanotechnology. Imperial college Press
3. Bharat Bhushan (2007) Springer Handbook of Nanotechnology. Springer Verlag.
4. Challa S., S. R. Kumar, J. H. Carola (2006) Nanofabrication towards biomedical application: Techniques, tools, Application and impact. John Wiley and sons.
5. Robert A. Freitas Jr (2003) Nanomedicine, Vol. I: Basic Capabilities.
6. Neelina H. Malsch (2005) Biomedical Nanotechnology. Taylor and Francis. CRC press.
7. Patrick Boisseau, Marcel Lahmani (2009) Nanoscience: Nanobiotechnology and
8. Ralph S. Greco, Fritz B. Prinz, R. Lane Smith (Editors) (2004) Nanoscale Technology in Biological Systems. CRC Press
9. Harry F. Tibbals (2010) Medical Nanotechnology and Nanomedicine. CRC Press
10. Research articles from various journals and databases

## M. Sc. in Nanoscience and Technology,
## Part I, Semester–I

### CP-6-Quantum Mechanics at Nanoscale

| Sr. No. | Topics | No. of Lectures |
|---|---|---|
| **Unit I** | **Problems on Quantum Mechanics:** Solved problems on matter waves, Schrodinger equation, wave-particle duality, Heisenberg Uncertainty principle, Operators and related topics. | **15** |
| **Unit II** | **Nanomaterials Continuum:** Basic Quantum Mechanics and Solid States, Materials Properties and Phenomenon at macro and nanoscale, Quantization of Energy, Bohr Exciton Radius, Nano quantum prospective, Particle in a box, Two-Dimensional Quantum System, Zero-dimension materials: clusters, cluster particle in a box, Optical Properties of Clusters, Dipolar Plasma Resonance, Other Physical Properties and Phenomena: Surface Energy, Thermal Properties. Quantum wire, Quantum Size Effects and Scaling laws. | **15** |

**Reference Books:**


1. Introduction to Nanoscience and Nanotechnology. By Gabor L. Hornyak, H.F. Tibbals, Joydeep Dutta, John J. Moore.
2. Introductory Quantum Mechanics for Applied Nanotechnology By Dae Mann Kim, 2016
3. Concepts of Modern Physics, Arthur Beiser, Ahobhit Mahajan, S. Rai Choudhury, Sixth Edition, Tata McGraw Hill Education Private Ltd.
4. Modern Physics, S. L. Kakani and Shubhra Kulkarni, 2006, Viva books Private Ltd.

5. Modern Physics, D. L. Sehgal, K. L. Chopra and N. K. Sehgal, Reprint 1995, Sultan Chand & sons.
6. Introduction to Modern Physics, F. K. Richtmyer, E. H. Kennard, John N. Cooper, Sixth Edition, Tata McGraw Hill Education Private Ltd
7. A Text book of Quantum Mechanics, P.M. Mathews & K. Venkatesan, 2nd Edn.,2010, Tata McGraw Hill,
8. Quantum Mechanics, Leonard I. Schiff, 3rdEdn. 2010, Tata McGraw Hill.
9. Quantum Mechanics Theory and Applications, A. K. Ghatak and S. Lokanathan, Third Edn.1995, Macmillan India Ltd.

**Shivaji University, Kolhapur,**
**School of Nanoscience and Technology,**
**M. Sc. in Nanoscience and Technology, Programme,**
**Part-I under CBCS Pattern (2021-22)**

## Semester–II

### CP-7-Solid State Electronic Devices

| Sr. No. | Topics | No. of Lectures |
|---|---|---|
| **Unit I** | **Transistors and Microwave Devices:** Bipolar junction transistor (BJT), frequency response and switching of BJT, Single electron transistor, Field effect transistor (JFET), MOSFET and MESFET devices: structure and its operation, Tunnel diode, Resonant tunneling and NDR effects in nanostructures, Transferred electron devices-Gunn diode, Nano-CMOS technology. | **15** |
| **Unit II** | **Photonic Devices:** Radiative Transitions and Optical Absorption, Light emitting Diodes, OLED, Infrared LED, Photodetector, Photoconductor, Photodiode, Semiconductor Lasers, Laser Operation, population inversion, carrier and optical confinement, optical cavity | **15** |
| **Unit III** | **Nanopiezotronics, nano-generators and Micro-Electro-Mechanical-Systems (MEMS):** Piezoelectric, Electrostrictive and magnetostrictive effects, important materials exhibiting the properties and their applications sensors and actuator devices, Piezoelectricity of ZnO nanowires, combination of piezoelectric and semiconducting properties, Piezotronic nanodevices using ZnO nanowires, chemical/humidity nanosensors, ZnO | **15** |

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| | nanowires, nano-generator, Flexible nanogenerator, and power fibers. What is MEMS, MEMS technology? A brief history of MEMS, Introduction of MEMS sensors, physical/chemical/biological MEMS sensors, Resonant mechanical sensors, accelerometers, gas flow sensors, sensing principle, MEMS design, MEMS in automobiles | |
| **Unit IV** | **Memory:**<br>Introduction, The non-volatile memory (NVM) market, and applications, Development in charge storage memory technology: Floating gate concept-NOR flash technology-NAND flash technology-Flash memory scaling. Advanced Memory Storage Concept: Ferroelectric Memories (FeRAM), Magnetoresistive Memories (MRAM), Resistive RAM (ReRAM and RRAM), and Phase Change Memories (PCM). | **15** |

**Reference Books:**


1.Semiconductor devices:Physics and Technology 2nd Edition, S. M. Sze

2.Modern Digital Electronics: R.P.Jain

3. Introduction to Semiconductor devices by M. S. Tyagi

4. Optical electronics by Ajoy Ghatak and K. Thyagrajan, Cambridge University Press.

5. microsystems and nanotechnology, Xudong Wang, Jun Zhou, Zhong Lin Wang, Springer Publication.

6. Advances in Non- volatile Memory and Storage Technology, Yoshio Nishi, Woodhead Publishing Series in Electronic and Optical Materials (Elsevier), 2014.

7. Selected Advances in Nanoelectronic Devices: Logic, Memory and RF, Mojtaba Joodaki, Springer, 2010.

## M. Sc. in Nanoscience and Technology,
## Part I, Semester–II

### Title of the paper: Laboratory Course-I

| Sr. No. | Name of the Experiment |
|---|---|
| **1.** | BJT Characteristics |
| **2.** | FET Characteristics |
| **3.** | Modeling and simulation of Solar cell |
| **4.** | Modeling and simulation of PN Junction |
| **5.** | Modeling and simulation of MOSFET device |
| **6.** | Studies on TiO2 Memristor |
| **7.** | Studies on Liquid memristor devices |
| **8.** | Studies on Physical sensors |
| **9.** | Studies on Chemical sensors |
| **10.** | Studies on MEMS device |

## M. Sc. in Nanoscience and Technology, Part I, Semester–II

### CP-8-Energy Conversion and Storage Devices

| Sr. No. | Topics | No. of Lectures |
|---|---|---|
| **Unit I** | **Solar Photovoltaics:**<br>P-N junction under illumination, Light generated current, I-V equation, Characteristics, Upper limits of cell parameters, losses in solar cells, equivalent circuit, effects of various parameters on efficiency, Solar cell design, Design for high Isc, Anti Reflective coating (ARC), Design for high Voc and fill factor, Analytical techniques; solar simulator, Quantum efficiency, Minority carrier lifetime and diffusion length measurement. | **15** |
| **Unit II** | **Sensitized and Polymer Photovoltaics:**<br>Dye sensitized solar cells, advantages and disadvantages, Quantum dot sensitized solar cells, Perovskite sensitized solar cells, Planar and bulk heterojunction polymer solar cells, Exciton generation and dissociation, Advantages, disadvantages and types of materials. | **15** |
| **Unit III** | **Batteries:**<br>Primary batteries, Rechargeable batteries, Electrochemical energy storage: cell reaction, Laws, Parameters, thermodynamics parameters, kinetic parameters, Polarization, Heat effects, Types of batteries (Lead-acid, Ni/Cd, Ni/metal hybrid), charging methods and techniques, characteristic curves, Lithium | **15** |

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| | batteries, chemistry and Physics of lithium batteries, anode and cathode materials, applications | |
| **Unit IV** | **Supercapacitors:** Similarities and differences between supercapacitors and batteries, Energetics, Double layer electrostatic capacitor, Pseudocapacitance, origin, kinetic theory, RuO2 as a material for electrochemical capacitors, Regon plot, electrolyte factor, energy density and power density, Impedance of a pseudocapacitance. | **15** |

**Reference Books:**


1. Solar photovoltaics, Fundamentals, Technologies and Applications by Chetan Singh Solanki, PHI Learning Private Limited, Delhi-110092.
2. Polymer photovoltaics, a practical approach by Fredrik C. Krebs, Spie Press, Bellingham, Washington USA.
3. Organic Solar Cells, Theory, Experiment, and Device Simulation by Wolfgang Tress, Springer.
4. Dye Sensitized Solar Cells by K. Kalyansundaram, EPFL Press, A Swiss academic publisher distributed by CRC press.
5. Solar cells- Dye-sensitized Devices by Leonid A. Kosyachenko, Published by Intech, Janeza Trdine 9, 51000 Rijeka, Croatia.
6. Battery Technology Handbook by H. A. Kiehne , Marcel Dekker, Inc. , New York, Basel.
7. Electrochemical Supercapacitors, Scientific fundamentals and Technological Applications by B. E. Conway, Kluwer Academic/ Plenum Publishers, New York, Boston, Dordrencht, London, Moscow.

## M. Sc. in Nanoscience and Technology,
## Part I, Semester–II

**Title of the paper: Laboratory Course-II**

| Sr. No. | Name of the Experiment |
|---|---|
| 1 | Study of P-N junction solar cell characteristics |
| 2 | Fabrication of TiO2 based dye sensitized solar cell |
| 3 | Study of characteristics of TiO2 based dye sensitized solar cell |
| 4 | Effect of temperature on lead-acid battery cell performance |
| 5 | Effect of concentration of reactive species on lead-acid battery cell performance |
| 6 | Studies of electrolysis of water and electricity generation by fuel cell |
| 7 | Fabrication of MnO2 thin film pseudocapacitor and study of its CV cycle |
| 8 | Determination of power density and energy density from given data |

# M. Sc. in Nanoscience and Technology,
# Part I, Semester–II

### CP-9- Fundamentals of Nanocatalysis and Applications

| Sr. No. | Topics | No. of Lecture |
|---|---|---|
| **Unit I** | Introduction to catalysis, classifications, heterogeneous catalysis, reaction on the solid surfaces, adsorption isotherms, physisorption and chemisorptions., reaction mechanism and kinetics of the heterogeneous catalytic reactions, activation energy (Arrhenius equation, Eyring equation). | **15** |
| **Unit II** | Catalytic activity (bulk and nanoscale), catalytic activity determination for metal/metal oxide nanostructures. Langmuir-Hinshelwood mechanism for nanocatalyst, Mass transport, diffusion controlled process, catalytic efficiency and turnover frequency, inhibition. Application of metal nanoparticles in organic reactions (Heck and Suzuki-Maurya reactions), environmental remediation. | **18** |
| **Unit III** | Introduction of photocatalysis, Basics of electrochemistry and photochemistry, Electronics structure and photoabsorption, Kinetics and photocatalytic activity, Jablonskii diagram, Structure of photocatalysts and solar spectrum analysis. Fundamental understanding of semiconductor interfaces, Principles and relevance to photoelectrochemical and photocatalysis mechanism, Properties of good photocatalysts, Advantages of photocatalysts, types of photocatalysts, Homogeneous, heterogeneous, carbonaceous and plasmonic | **15** |

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| | photocatalysts. | |
| **Unit IV** | Photocatalysts design and synthesis, Application of photocatalysis, Self cleaning, purification of water and air, Photoreduction of CO2 and fuel production, antimicrobial use. Characterization and performance of photocatalysts, Fabrication of water purification reactor, Industrial development of photocatalysts, Environmental remediation, Future possibilities. | **12** |

**Reference Books:**


(1) J. P. Simons, Photochemistry and Spectroscopy, Wiley, 1971.

(2) J. G. Calvert, J. N. Pitts, Photochemistry, Wiley & Sons, New York, 1966.

(3) N. Serpone, E. Pelizzetti (Eds.), Photocatalysis. Fundamentals and Applications, Wiley, New York, 1989.

(4) K. K. Rohatgi-Mukherjee, Fundamentals of Photochemistry, Wiley, New York, 3rd Edition, 2002.

(5) Nick Serpone and Ezio Pelizzetti, Photocatalysis: Fundamentals and Application, Wiley Interscience, 1st Edition, 1989

(6) Photoelectrochemistry, Photocatalysis and Photoreactors Fundamentals and Developments, Schiavello, Mario (Ed.) Springer,1985.

(7) Photoelectrochemical solar cells, Suresh Chandra, Gordon and Breach Science Publishers, 1985.

(8) Physical Chemistry of Surfaces , W. Adamson, Wiley Intersciences,(5th edition) 1990.

(9) Physical chemistry - Peter Atkins, Julio de Paula , 7th Edition Oxford University Press.

(10) Catalytic Chemistry, B.C. Gates, John Wiley and Sons Inc. (1992)

(11) Nanoparticles and Catalysis; D. Astruc, Wiley-VCH, 2008

(12) Heterogeneous Catalysis, D.K. Chakrabarty and B. Viswanathan, New Age Publishers

## M. Sc. in Nanoscience and Technology,
## Part I, Semester–II

**Title of the paper: Laboratory Course-III**

| Sr. No. | Name of the Experiment |
|---|---|
| 1 | Adsorption isotherms, validation of Langmuir and Freundlich isotherms |
| 2 | Determination of order of reaction for acid catalyzed iodination of Acetone. |
| 3 | Measurement of Ag/Pt/Pd nanoparticle catalysed reduction of 4-nitro phenol to 4-amino phenol spectrophotometrically and determination of pseudo-first order kinetics. |
| 4 | Synthesis of C-C bond by Pd nanoparticle catalyzed Suzuki-Miyaura coupling of boronic acid and iodobenzene. |
| 5 | Calculation of activation energy of a nanocatalyzed reaction from the given data. |
| 7 | Calculation of entropy of activation, enthalphy of activation for a nanocatalyzed reaction. |
| 8 | Measurement of TiO2/ZnO/Fe2O3 nanoparticle catalyzed photodegradation of dye and calculation of efficiency. |

**Reference Books:**

1. M. Sc. Nanocatalysis Laboratory Manuals (School of Nanoscience and Technology)

## M. Sc. in Nanoscience and Technology,
## Part I, Semester–II

### CP-10-Nanomagnetism and Spintronics

| Sr. No. | Topics | No. of Lecture |
|---|---|---|
| **Unit I** | **Fundamentals of Nanomagnetism and spintronics:** **Magnetism in small structures:** Single domain particles, superparamagnetism, blocking temperature, magnetic ultrathin films, magnetic surface and interface anisotropies. **History and overview of spin electronics:** Classes of magnetic materials; The early history of spin; Quantum Mechanics of spin; Spin relaxation; Spin injection, spin accumulation, and spin current, Spin dependent transport. | **15** |
| **Unit II** | **Spintronic devices:** mechanism of GMR, spin dependent scattering of electrons, exchange biasing, spin valves, quantum tunneling, tunneling magnetoresistance (TMR), magnetic oxides and phase transformations: colossal magnetoresistance (CMR), Spin hall effect, Spin electronic devices. | **15** |
| **Unit III** | **Magnetic data storage:** Magnetic recording overview, recording medium, particulate recording media, thin film recording materials, longitudinal versus perpendicular recording, write heads, read heads, magnetic random access memory (MRAM), outlook and fundamental limits to recording, patterned media. | **15** |

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| **Unit IV** | **Nano Biomagnetism:**<br>Materials for biomagnetism, targeting, functionalization of magnetic nanoparticles, magnetic separation, manipulation of magnetic particles in fluids magnetic twizzers, drug and gene delivery, magnetic resonance imaging, hyperthermia, magnetic biosensors, biological assay system, labon-a-chip concept. | **15** |

**Reference Books:**


1. Modern magnetic materials, Robert C. O'Handley, John Wiley & Sons Inc., 2000.
2. Introduction to magnetic materials, Cullity and Graham, John Wiley & Sons Inc., 2009.
3. Introduction to magnetism and magnetic materials, D. Jiles, Chapman and Hall pub., 1991.
4. Fundamentals of Magnetism, Mathias Getzlaff, Springer, 2008.
5. Spin Electronics, M. Ziese and M.Thornton (Eds.), Springer, 2001.
6. Advanced Magnetic Nanostructures, Sellmyer and Skomski (Eds.), Springer, 2006.
7. Introduction to Spintronics, S. Bandyopadhyay, M. Cahay, CRC Press, 2008.
8. Magnetoelectronics, M. Johnson, Academic Press 2004.
9. Advanced Magnetic Nanostructures, D. J. Sellmyer, R. Skomski, Springer, 2006.
10. Concepts in Spin Electronics, S. Maekawa, Oxford University Press, 2006.
11. 5. Spin Electronics, D.D. Awschalom, R.A. Buhrman, J.M. Daughton, S.V. Molnar, and M.L. Roukes, Kluwer Academic Publishers, 2004.

## M. Sc. in Nanoscience and Technology,
## Part I, Semester–II

### CP-11-Biomedical Application of Nanobiotechnology

| Sr. No. | Topics | No. of Lectures |
|---|---|---|
| **Unit I** | **Cancer as a disease:** Malignant and benign growth in Cancers, difference between normal cell function and malignant cells, Types of cancer, causative agents of cancer, concept of oncogenes, proto-oncogenes, Gross tissue level changes in cancer, cellular events, molecular pathology, Early detection of cancers using nanotechnology, Biomarker development by nanoprobes, Conventional chemotherapy drugs their mechanism and limitations, Nanodrugs in cancer chemotherapy in details (synthesis, action, advantages, examples), Potential of nanotech application in cancer surgery. Introduction to genome /proteome analysis for cancer Nanobiotechnology for drug discovery, protein and peptide based compounds for cancer and diabetes, drug delivery, nanoparticle based drug delivery, lipid nanoparticles, vaccination, cell therapy, Gene therapy. | **15** |
| **Unit II** | **Nanoparticles in Biological systems and Nanodiagnostics:** bone substitutes and dentistry, Implants and Prosthesis, Reconstructive Intervention and Surgery, Nanorobotics in Surgery, Photodynamic Therapy, Neuro-electronic Interfaces – Protein Engineering, Drug delivery, Therapeutic applications. Nano diagnostics, Nanoarrays for diagnostics, detection of single DNA, self assembled protein nanoarrays, protein nanobiochip, nanoparticles for molecular diagnostics, DNA nanomachines. | **15** |

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| **Unit III** | **Nanodrug delivery/administration:** Nanodrug delivery / administration, Polymer nanoparticles for drug and small silencing RNA delivery to treat cancers of different phenotypes. polymer NPs for miRNA delivery, polymer NPs for antisense miRNA, (antagomir) delivery, polymer NPs for siRNA delivery, polymer NPs for shRNA delivery, advantages and disadvantages associated with the use, of polymer NPs for drug, delivery, mechanism of drugs deliver to tumors by Polymer nanoparticles. Nanodevices for drug delivery and theranostics. Introduction to the potentials applications and challenges of nanomedicine. Nanomedicine and tissue engineering, nanobiomachines and nanorobots. | **15** |
| **Unit IV** | **Biological Interactions with nanomaterials and Nanotoxicology:** Introduction to Biocompatibility, Toxicity, Cytotoxicity, Hypersensitivity, Carcinogenicity, Fate of nanomaterials in the body: short term and long term effects.<br>Interaction of Materials with Soft Tissues, Inflammation, Granulation Tissue Formation, Foreign Body Reaction, Fibrosis, Modification of Blood-Biomaterial Interactions, Interaction with Blood by Heparin, Interactions with Proteins, Cell Adhesion, Interactions with Hard Tissues, The Vroman Effect, Adhesion of Osteoblasts, Osseointegration, Fibrous Capsule Formation, Safety Testing of Biomaterials.<br>Introduction, Toxicity of nanoparticles, Types of Nanoparticles causing Toxicity, Target organ toxicity, Exposure, Uptake, and Barriers, Experimental Models in Nanotoxicology - In vitro Models, In Vivo Models, Predicting Penetration and Fate of Nanoparticles in the Body, Toxicity Mechanisms - Mechanisms for Radical | **15** |

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| | Species Production, General Genotoxicity Mechanisms, Detection and Characterization of Genotoxicity. | |

**Reference Books:**


1. Challa Kumar- Biological and pharmaceutical Nanomaterials, Wiley-VCH Verlag GmbH & Co. KGaA.
2. Cato T. Laurencin and Lakshmi S. Nair, Nanotechnology and Tissue Engineering The Scaffold, CRC Press taylor& Francis Group.
3. Peter X Ma, Scaffolds for tissue fabrication, materials today Volume 7, Issue 5, May 2004, Pages 30– 40
4. K.K.Jain, Nano Biotechnology, Horizions Biosciences, 2006
5. Martin C. Woodle , Patrick Y. LuNanoparticles deliver RNAi therapy, materialstoday,Volume 8, Issue 8, Supplement, August 2005, Pages 34–41
6. C. Kumar, Nanomaterials for medical diagnosis and therapy, Wiley –VCH, 2007, USA
7. Harry F. Tibbals (2010) Medical Nanotechnology and Nanomedicine. CRC Press
8. Assessing Nanoparticle Risks to Human Health, Gurumurthy Ramachandran, Elesvier, 2011
9. Nanotechnology: Environmental Health and safety, Risks, Regulation and Management, Matthew Hull and Diana Bowman, Elsevier, 2010
10. Nanotechnology: Health and Environmental Risks, Jo Anne Shatkin, CRC Press, 2013
11. Principles and Methods of Toxicology, A.W. Hayes, Informa Health care, 2008

## M. Sc. in Nanoscience and Technology,
## Part I, Semester–II

**Title of the paper: Laboratory Course-IV**

| Sr. No. | Name of the Experiment |
|---|---|
| 1 | Conjugation of nanoparticles with nucleic acids, DNA/RNA, Amino acids |
| 2 | Conjugation between PGLA and tetracycline |
| 3 | Preparation of PGLA-tetracycline functional nanoparticles using emulsion diffusion method/ nano-precipitation/dialysis method |
| 4 | Characterization of tetracycline modified nanoparticles |
| 5 | Synthesis and characterization of CdS quantum dots by reverse micelles method |
| 6 | Synthesis of oil based nanoemulsion drug delivery system |
| 7 | Testing the cell viability of metal oxide nanoparticles using tissue culture technique |
| 8 | In vitro study of the effect of nanoparticles on mammalian cells and tissues |
| 9 | MTT Assay for cell viability and growth |
| 10 | Cell counting and Cell staining using PI-DAPI |

**Reference Books:**


1. K. Youell and Firman, Nanotechnology perception 3 (2007) 75,96. Comprehensive overview of motors in biology
2. Jeremy Ramsden, Essentials of nanotechnology
3. Rammohan Devulapally and RamasamyPaulmurugan, Polymer nanoparticles for drug and small silencing RNA delivery to treat cancers of different phenotypes WIREs Nanomed Nanobiotechnol 2014, 6:40–60. doi: 10.1002/wnan.
4. Itamar Willner, Bernhard Basnar and Bilha Willner Nanoparticle–enzyme hybrid systems for nanobiotechnology FEBS Journal 274 (2007) 302–309.

5. Nanotechnology: Technology Revolution of 21st Century by Rakesh Rathi, published by S. Chand.
6. Introduction to Nanoscience, by Stuart Lindsay.
7. Introduction to Nanomaterials and nanotechnology by Vladimir Pokropivny, RynnoLohmus, Irina Hussainova, Alex Pokropivny and Sergey Vlassov.
8. Nanomaterials by A.K. Bandyopadhyay; New Age International Publishers.
9. Nanotechnology by Mark Ratner and Daniel Ratner, Pearson Education.
10. Nano Essentials, T.Pradeep /TMH
11. Bharat Bhusan, "Springer Handbook of Nanotechnology", springer, Newyork, 2007.
12. Hari Singh Nalwa, "Encyclopedia of Nanotechnology", USA 2011.
13. James A. Schwarz, Cristian I. Contescu, Karol Putyera, "Dekker encyclopedia of nanoscience and nanotechnology" CRC Press, 2004.
14. Charles P. Poole Jr. and Franks. J. Qwens (2003) Introduction to Nanotechnology. John Wiley and Sons.
16. Ehud Gazit (2007) Plenty of Room for Biology at the Bottom: An Introduction to Bionanotechnology. Imperial college Press
17. Bharat Bhushan (2007) Springer Handbook of Nanotechnology. Springer Verlag.
18. Challa S., S. R. Kumar, J. H. Carola (2006) Nanofabrication towards biomedical application: Techniques, tools, Application and impact. John Wiley and sons.
21. Robert A. Freitas Jr (2003) Nanomedicine, Vol. I: Basic Capabilities.
22. Neelina H. Malsch (2005) Biomedical Nanotechnology. Taylor and Francis. CRC press.
23. Patrick Boisseau, Marcel Lahmani (2009) Nanoscience: Nanobiotechnology and Nanobiology. Springer Publishers.
24. Ralph S. Greco, Fritz B. Prinz, R. Lane Smith (Editors) (2004) Nanoscale Technology in Biological Systems. CRC Press
25. Harry F. Tibbals (2010) Medical Nanotechnology and Nanomedicine. CRC Press Assessing Nanoparticle Risks to Human Health, Gurumurthy Ramachandran, Elesvier, 2011
26. Nanotechnology: Environmental Health and safety, Risks, Regulation and Management, Matthew Hull and Diana Bowman, Elsevier, 2010
27. Nanotechnology: Health and Environmental Risks, Jo Anne Shatkin, CRC Press, 2013
28. Principles and Methods of Toxicology, A.W. Hayes, Informa Healthcare, 2008

## M. Sc. in Nanoscience and Technology,
## Part I, Semester–II

### CP-12-Statistical mechanics and Nanothermodynamics

| Sr. No. | Topics | No. of Lectures |
|---|---|---|
| **Unit I** | **Statistical Mechanics:** Partition function and its significance. Rotational, translational, vibrational and electronic partition functions. Use of spectroscopic data for evaluation of various partition functions. Relationship between partition function and thermodynamic properties. Calculation of equilibrium constant using Partition function. | **15** |
| **Unit II** | **Nanothermodynamics:** Thermodynamics and Nanothermodynamics, Fundamental equations of thermodynamics, equilibrium constant and reaction kinetics, non-equilibrium thermodynamics, Applications of Classical thermodynamics to Nanothermodynamics, Hill theory for small systems, modern thermodynamics, Nanothermodynamics of single molecule. Heat transport at low-dimensions. | **15** |

**Reference Books:**


1. Introduction to Nanoscience and Nanotechnology. By Gabor L. Hornyak, H.F. Tibbals, Joydeep Dutta, John J. Moore.
2. Statistical Physics of Nanoparticles in the Gas Phase, By Klavs Hansen · 2018 Springer International Publishing.
3. Elements of statistical thermodynamics - L. K. Nash, 2ndEd. Addison Wesley 1974.
4. Thermal Transport in Low Dimensions : From Statistical Physics to Nanoscale Heat Transfer,2016, Stefano Lepri, Springer International Publishing.

5. An Introduction to Statistical Thermodynamics – T. L. Hill, Addison-Wesley. 1960. 15. Statistical Mechanics – Donald A. McQuarrie, 2000.