

**SCHEME OF TEACHING M.TECH (NANO SCIENCE AND NANO TECHNOLOGY)**  
**AND EXAMINATION SCHEME-2011-2012**

**FIRST SEMESTER**

| S.NO.   | SUBJECT  | SCHEDULE FOR TEACHING |   |       | THEORY             |       |       | PRACTICAL          |       |       | Subject Total | Credits |
|---------|--|-----------------------|---|-------|--------------------|-------|-------|--------------------|-------|-------|---------------|---------|
|         |  | L                     | P | TOTAL | Exam               | Sess. | Total | Exam               | Sess. | Total |               |         |
| MNT6101 | Quantum and Statistical mechanics                | 3                     | - | 3     | 50                 | 25    | 75    | -                  | -     | -     | 75            | 3       |
| MNT6102 | Principles of Biology and Biotechnology          | 3                     | - | 3     | 50                 | 25    | 75    | -                  | -     | -     | 75            | 3       |
| MNT6103 | Elements of Physical Chemistry                   | 3                     | - | 3     | 50                 | 25    | 75    | -                  | -     | -     | 75            | 3       |
| MNT6104 | Synthesis and Characterization of Nano-materials | 4                     | - | 4     | 50                 | 50    | 100   | -                  | -     | -     | 100           | 4       |
| MNT6105 | Scientific Computation and Simulation – I        | 2                     | 0 | 2     | 25                 | 25    | 50    | -                  | -     | -     | 50            | 2       |
| MNT6106 | Laboratory - I                                   | -                     | 5 | 5     | -                  | -     | -     | 25                 | 25    | 50    | 50            | 2       |
|         |  |                       |   |       | Total marks = 425; |       |       | Total credits = 17 |       |       |               |         |

**SECOND SEMESTER**

| Course.NO. | SUBJECT   | SCHEDULE FOR TEACHING |   |       | THEORY             |       |       | PRACTICAL          |       |       | Subject Total | Credits |
|------------|---|-----------------------|---|-------|--------------------|-------|-------|--------------------|-------|-------|---------------|---------|
|            |   | L                     | P | TOTAL | Exam               | Sess. | Total | Exam               | Sess. | Total |               |         |
| MNT6201    | Chemistry of Nanomaterials and Fabrication              | 4                     | - | 4     | 50                 | 50    | 100   | -                  | -     | -     | 100           | 4       |
| MNT6202    | Nano-bio-technology                                     | 4                     | - | 4     | 50                 | 50    | 100   | -                  | -     | -     | 100           | 4       |
| MNT6203    | Physics of Nanomaterials                                | 4                     | - | 4     | 50                 | 50    | 100   | -                  | -     | -     | 100           | 4       |
| MNT6204    | Semiconductor Devices, MEMS and NEMS                    | 4                     | - | 4     | 50                 | 50    | 100   | -                  | -     | -     | 100           | 4       |
| MNT6205    | Carbon Nanotube, its Functionalization and Nanofluidics | 4                     | - | 4     | 50                 | 75    | 100   | -                  | -     | -     | 100           | 4       |
| MNT6206    | Laboratory-II   | -                     | 5 | 5     | -                  | -     | -     | 25                 | 25    | 50    | 50            | 2       |
| MNT6207    | Scientific Computation & Simulation – II                | -                     | 3 | 3     | -                  | -     | -     | -                  | -     | 25    | 25            | 1       |
|            |   |                       |   |       | Total marks = 575; |       |       | Total credits = 23 |       |       |               |         |

**THIRD SEMESTER**

| S.NO.                                 | SUBJECT  | SCHEDULE FOR TEACHING |   |       | THEORY |       |       | PRACTICAL |       |       | Subject | Credits |
|---------------------------------------|--|-----------------------|---|-------|--------|-------|-------|-----------|-------|-------|---------|---------|
|                                       |  | L                     | P | TOTAL | Exam   | Sess. | Total | Exam      | Sess. | Total | Total   |         |
| MNT7101                               | Supramolecular and Surface Chemistry               | 4                     | _ | 4     | 50     | 50    | 100   | -         | -     | -     | 100     | 4       |
| MNT7102                               | Nanocomposites: Structure Properties & Performance | 4                     | _ | 4     | 50     | 50    | 100   | -         | -     | -     | 100     | 4       |
| MNT7103                               | Project & Thesis Preliminary                       | 2 <sup>⊕</sup>        | 8 | 10    | _      | _     | _     | _         | 150   | 150   | 150     | 5       |
| MNT7104                               | Laboratory - III                                   | _                     | 5 | 5     | _      | _     | _     | 25        | 25    | 50    | 50      | 2       |
| Total marks = 400; Total credits = 15 |  |                       |   |       |        |       |       |           |       |       |         |         |

**FOURTH SEMESTER**

|                                       |                  |                |    |    |   |   |   |     |   |     |     |    |
|---------------------------------------|------------------|----------------|----|----|---|---|---|-----|---|-----|-----|----|
| MNT7201                               | Project & Thesis | 5 <sup>⊕</sup> | 28 | 33 | - | - | - | -   | - | -   | *   | 19 |
| MNT7202                               | Seminar          | -              | -  | -  | - | - | - | 100 | - | 100 | 100 | 1  |
| Total marks = 100; Total credits = 20 |                  |                |    |    |   |   |   |     |   |     |     |    |

\* No numerical marks are to be assigned to thesis work. It is either “accepted” or “rejected”. Quality of work reported in the thesis can be graded in terms of “Very Good”, “Good” or “Average”.

**Total Marks (all semesters) = 1500**

**Total Credits (all semesters) = 75**

<sup>⊕</sup> In case of project, ‘lecture’ means theoretical work connected with it; e.g., literature survey, preparation of presentation material, etc.

## **COURSE CONTENTS**

**(Laboratory courses are at the end)**

### **MNT 6101 QUANTUM MECHANICS AND STATISTICAL MECHANICS**

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions/problems covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

#### **UNIT I**

**Introduction to Quantum Mechanics:** Failure of Classical Mechanics; Brief discussion of general ideas such as “Wave particle duality”, Uncertainty principle, Superposition principle etc.; Solutions of Schrodinger Equation for 1-D and 3-D square wells and potential barriers, H-atom.

**Matrix Mechanics:** Operators, Change of basis, eigen-values and Eigen-vectors; Simultaneous eigen vectors, Harmonic Oscillator in matrix mechanics; Exchange operators and identical particles.

**Angular Momentum:** Introduction to angular momentum operators; Eigenvalues and Eigen vectors of  $L^2$ ,  $L_z$ , Spin and  $J^2$ ,  $J_z$ .

#### **UNIT II**

**Approximation Methods:** Non- Degenerate and degenerate perturbation theory and application to anharmonic oscillator, variational method with application to ground state of harmonic oscillator and hydrogen atom, General expression for the probability of transition from one state to another, constants and harmonic perturbation.

**Scattering Theory:** Scattering Cross section and scattering amplitude, partial wave analysis, Bohr approximation and its application to potentials.

#### **UNIT III**

**Theory of Ensembles:** The microcanonical Ensemble theory and its application to ideal gas of monoatomic particles; The canonical ensemble and its thermodynamics; Partition function; Energy fluctuations; Equipartition; A system of harmonic oscillators as canonical ensemble; The grand canonical ensemble and significance of statistical quantities.

#### **UNIT IV**

**Quantum Statistics:** Quantum states and phase space, the density matrix, a few examples, An ideal gas in quantum mechanical ensembles; statistics of occupation numbers; Basic concepts and thermodynamic behaviour of an ideal Bose gas, Bose- Einstein Condensation; Discussion of a gas of phonons, Thermodynamic of a Fermi gas, heat capacity of a free electron gas at low temperatures; Pauli paramagnetism.

#### **Books and Suggested Readings:**

1. *Concepts of Modern Physics* – Arthur Beiser, McGraw-Hill Education.
2. *Quantum Mechanics* – Leonard I. Schiff, Tata McGraw Hill
3. *Quantum Mechanics: Theory and Applications*– S. Lokanathan and A. Ghatak, Macmillan India Limited
4. *Heat and Thermodynamics* by M. W. Zymansky, R. H. Dittman, McGraw-Hill
5. *Statistical Physics* by K. Huang, Wiley
6. *Statistical Physics Part 1: Volume 5 (Course of Theoretical Physics, Volume 5)* -L. Landau &I. M. Lifshitz, Butterworth-Heinemann

### **MNT 6102 PRINCIPLES OF BIOLOGY AND BIOTECHNOLOGY**

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

## UNIT I

**Cell Structure and Physiology:** Cell: structure, function and types, Cell multiplication, Biomolecules; carbohydrates, Proteins, Lipids, Nucleic Acids, Cellular metabolism: Energy yielding and energy requiring pathways, Transport of nucleus across cell membrane.

## UNIT II

**Microbes:** Structure, growth, isolation, preservation, DNA replication, genetic recombination.

## UNIT III

**Immunology:** Cells and organs of immune systems, Antigen and Antibodies: Cell mediated immunity, Culturing of cells, stem cells, Immuno dygnostics, Cancer, Graft rejection.

**Enzymology:** Classification, Kinetics, Mechanism of action, purification, applications.

## UNIT IV

**DNA Technology:** Restriction enzymes, gene cloning technology, PCR, DNA probes, DNA sequencing, Oligonucleotide synthesis, DNA microarray systems.

### Books and Suggested Readings

1. *Modern Bioelectricity* by A. A. Marino, Marcel Dekker Inc New York, 1998
2. *Biophysics* by P. V. Gautham, Narosa Publishing House, New Delhi, 2002
3. *Biometals* by S. V. Bhat, Narosa Publishing House, New Delhi, 2002
4. *Biophysics* by R. N. Roy, New Central Book Agencies (P) Ltd, 1996

## MNT 6103 ELEMENTS OF PHYSICAL CHEMISTRY

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions/problems covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

## UNIT I

**Introduction :** The scope of nano material chemistry, the nanoscale systems, Defining nano dimensional materials, Size effects in nano materials, Application and technology development, General methods available for the synthesis of nano dimensional materials.

**Atomic and Molecular Basics:** Particles and Bonds, Chemical bonds in Nano technology, the shapes of molecules, additional aspects of bonding, molecular geometry: VSEPR Model, hybridization Van der Waals interactions, Dipole–Dipole Interactions, Ionic Interactions, Metal bonds, Covalent bonds, coordinative bonds, Hydrogen bridge bonds and polyvalent bonds.

## UNIT II

**Surface Chemistry:** Adsorption and absorption, Adsorption isotherms, Freundlich adsorption isotherm, Langmuir adsorption isotherm, B.E.T. theory of multilayer adsorption, Gibbs adsorption isotherm, Application of adsorption.

## UNIT III

**Colloids:** Classification of Colloids, Preparation of colloidal solutions, Purification of colloidal solution, Properties of colloidal solution, Emulsion, Gels, Uses of colloids, Micelle formation, The critical micellization concentration, Factors affecting the c.m.c.

## UNIT IV

**Crystalline Structure:** Crystalline and amorphous solids, Isotropy and anisotropy, Crystal systems, Elements of symmetry, Space lattice and unit cell, Bravais lattice, Miller indices, imperfection in a crystal, points defects, line defects, Dislocations.

**Thermodynamics of surfaces:** Introduction, Surface energy and its cosequences, Thermodynamics of surfaces, The Gibbs adsorption equation, Thermodynamic behaviour of small particles, Homogenous nucleation.

### Books and Suggested Readings:

1. *Physical Chemitry* by P. W. Attkins , Oxford Press
2. *Introduction to Modern Colloid Science* by Robert J. Hunter, Oxford University Press.
3. *Nanoscale Materials in Chemistry* by Kenneth J. Khabhunde (ed.) Wiley Interscience.
4. *Thermodynamics and Statistical Mechanics* by A N Tikhonov, Peter Theodore Landsberg
5. *Thermodynamics and Statistical Mechanics* by John M. Seddon, J. D. Gale

## MNT 6104 SYNTHESIS AND CHARACTERIZATION OF NANOMATERIALS

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions/problems covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

### UNIT I

**Review of fundamental behaviour** of 0-D(nanoclusters), 1-D(nanowires), 2-D(thin film multilayers), and 3-D(bulk nanostructures) materials. Introduction to size dependent phenomenon in nanostructure for various application, specific production techniques like chemical vapor deposition, arc gnition etc. Formation of clusters and nanoparticles from supersaturated vapor and selected properties, sputtering and thermal evaporation and laser methods. Synthesis of nanoparticles by chemical routes.

### UNIT II

**General principles for synthesis** of monodispersed nanoparticles, metals and intermetallics, Ceramics, composites, nanoparticles via organized membrane, clusters, magnetic particles, synthesis of semiconductor nanoparticles, colloids/Micelles/vesicles/Polymers/glasses, Crystalline, and zeolite hosts.

### UNIT III

**Synthesis – II:** Mechanical attrition, high energy ball milling, and mechanical attrition, nanocomposites by mechano-chemistry, mechanism of grain size reduction, property of microstructure relationships.

**Characterization techniques I :** Tools in nanotechnology: Scanning electron microscopy(SEM), Transmission electron microscopy and high resolution(TEM), energy dispersive spectroscopy(EDX)

### UNIT IV

**Characterization techniques II :** Electron energy loss(EELS), X- ray photoelectron and auger electron spectroscopy(XPS, AES), Scanning tunneling microscopy(STM) and spectroscopy(STS), Atomic force microscopy(AFM), Magnetic force microscopy(MFM), Chemical Force Microscopy(CFM), Focused ion beam, nanolithography, powder x-ray diffractometry, UV visible, Infrared/ Raman, EPR and NMR.

### Books and Suggested Readings

1. *Handbook of Semiconductor Nanostructures and Nanodevices Vol 1-5-* A. A. Balandin, K. L. Wang.
2. *Springer Handbook of Nanotechnology* by Bharat Bhushan
3. *Encyclopedia of Nanotechnology-* Hari Singh Nalwa.
4. *Nanofabrication towards biomedical application: Techniques, tools, Application and impact* – Ed. Challa S., S. R. Kumar, J. H. Carola.

## MNT 6105 SCIENTIFIC COMPUTATION AND SIMULATION – I

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions/ problems covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

### UNIT I

**Tools:** Practical approach to learning operating systems (DOS, UNIX, Windows) and Graphical packages (Origin, Gnuplot

**Programming:** Fortran and C<sup>++</sup>: Character set, variables, constants, Data types and their declarations, relational operators, logical operators, arithmetical operations, built in functions, input output statements, functions, subroutine, Array handling.

### UNIT II

**Numerical Methods I :** Matrices, Solution of system of linear equations, direct methods, error analysis, curve fitting, iterative methods; Numerical differentiation and integration methods, quadrature formula and Monte-Carlo methods, Numerical methods for ordinary equations, stability and convergence.

### UNIT III

**Numerical Methods II:** Interpolation, extrapolation, Numerical solution of partial differential equation, Initial value problems.

**Random numbers:** Monte carlo integral methods, importance sampling, fast fourier transform.

### UNIT IV

**Physical simulations:** N body methods and particle simulations, Verlet algorithm, molecular dynamics and monte carlo methods. Simulation of small system and Ab initio methods.

**Laboratory:** Five open ended experiments based on Fortran, C++ and on numerical methods.

#### Books and Suggested Readings:

1. *Numerical Methods for Scientific and Engineering Computation*, M. K. Jain, S. R. K. Iyengar and R. K. Jain, Wiley Eastern
2. *Handbook of Theoretical and Computational Nanotechnology*, Eds. Michael Rieth and Wolfram Schommers, 2006
3. *Introductory Computational Physics* Andi Klein and Alexander Godunov (Cambridge)

## MNT 6201 CHEMISTRY OF NANOMATERIALS AND FABRICATION

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions/problems covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

### UNIT I

**Building Blocks of Nanotechnology:** covalent architecture, coordinated architecture and weakly bound aggregates, Interactions and topology

**Chemical Properties:** The effect of nanoscale metals on chemical reactivity, effect of nanostructure on mass transport, metal nanocrystallites supported on oxides, supported nanoscale catalysts.

### UNIT II

**The effect of chemistry of nanostructures:** Modification of nanoparticles, Langmuir Blodgett films, Self assembled surface films, Binding of molecules on solid substrate surfaces, molecular nanostructures, strategies of molecular construction, Synthetic supramolecules.

### UNIT III

#### Applied chemistry of nanomaterials:

Application to fundamental studies.

Industrial applications: Photographic materials, ceramic materials, magnetic particles for recording media, catalysts, fuel cells electrocatalysis, pigments, nanostructured materials as new chemical reagents, nanocomposite polymers, fluids, inks and dyes, block copolymers and dendrimers.

Analytical and Environmental chemistry of nanoparticles: chemical and biological nanosensors, controlled pore size materials (zeolites, MCM-41 and other controlled pore silicates, pillared clays), green chemistry, Environmental impact of fine particles.

### UNIT IV

**Fabrication:** Crystal growth and wafer preparation, defects, clean room concept, wafer cleaning techniques, oxidation, diffusion, Epitaxy, Ion implantation, Metallization, Lithography, Etching, masking sequences and bipolar and MOS device fabrication process flow, Integration of unit process, process modeling, Topological design rules, passive device such as registers and capacitors and their non idealities, fabrication of nanoelectronics structures.

#### Books and Suggested Readings

1. *Nanoscale Materials in Chemistry* by Kenneth J. Khabunde (ed.) Wiley Interscience.
2. *Nanotechnology – An introduction to nanostructure of technique* by Michel Kohler and Wolfgang Fritzsche 2004- Wiley VCH
3. *Materials Engineering* by V. Raghavan, Prentice Hall.

## MNT 6202 NANOBIO TECHNOLOGY

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

### UNIT I

**Biophysics:** Bioelectromagnetism, Bioenergetics, Biomechanics, Biomaterials, Biological rhythms, Neurotransport.

### UNIT II

**Bioinformatics:** Use of databases in biology, Sequence bases EMBL, NBAF, Protein structural databank, Sequence analysis of proteins and nucleic acids, structure prediction, simple molecular modeling.

### UNIT III

**Applications:** Nanotherapeutics, Molecular diagnostics, tissue engineering, nanopump, and biological harvests, nanorobotic cells, molecular motors, nanomembranes, Organic molecular based computers, bionanodevices(sensors & actuators).

### Books and Suggested Readings

1. *Modern Bioelectricity* by A. A. Marino, Marcel Dekker Inc New York, 1998
2. *Biophysics*, PV Gautham, Narosa Publishing House, New Delhi, 2002
3. *Biometals* by SV Bhat, Narosa Publishing House, New Delhi, 2002
4. *Nanostructures and Nanomaterials* by G. Cao, Imperial College Press, 2004
5. *Introduction to Bioinformatics* by L. A. Lesk, Oxford University Press, 2003
6. *Biophysics* by RN Roy, New Central Book Agencies (P) Ltd, 1996

## MNT 6203 PHYSICS OF MATERIALS AND NANOMATERIALS

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions/problems covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

### UNIT I

**Resume of structure, binding, lattice dynamics and thermal properties:** Lattice structures, bindings in solids, Elastic constants, lattice vibrations, normal modes, Density of states, thermal expansion.

**Energy band theory:** Review of electrons in a periodic potential, nearly free electron model, tight binding method, bands in pure and doped semiconductors.

### UNIT II

**Transport Theory:** Electronic transport from classical kinetic theory, calculation of relaxation time in metals and insulators, Hall effect and magnetoresistance.

**Basic ideas of Dielectric and magnetic properties of metals;** Polarization mechanisms, Dielectric function from oscillator strength, Clausius-Mosotti relation, piezo, pyro and ferroelectricity, basics of ferromagnetism in materials.

### UNIT III

#### Nanomaterials Foundations:

Introduction: Definition, historical perspective, effects of nanoscience and nanotechnology on various fields; Classification of nano-structured materials, top down and bottom up approaches of generation

#### Properties of nano-structured materials

Size and shape dependent properties, color, melting point, magnetism, density of states, conductivity and band gap, metal to insulator transition;

### UNIT IV

**Mechanical** properties of nano-materials; **Magnetic** and **electronic transport** properties of nano-structured materials.

**Quantum Dots:** Electron confinement in various dimensions, single and interacting quantum dots, self organized quantum dots, spectroscopy of quantum dots, nanocrystal superlattices.

### Books and Suggested Readings

1. *Introduction to Solid State Physics VIIIth Ed.* by C. Kittel
2. *Introduction to Nanotechnology* by Owen and Poole, Wiley
3. *Nano-materials* by A. K. Bandopadhyay, New Age International
4. *Quantum Wells, Wires & Dots: Theoretical & Computational Physics of Semiconductors Nanostructures* by Paul Harrison, Wiley International
5. *Nanostructures and Nanomaterials - Synthesis, Properties and Applications* by Cao, Guozhong

## MNT 6204 SEMICONDUCTOR DEVICES, MEMS AND NEMS

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions/problems covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

### UNIT I

**Review:** review of physics and properties of semiconductor, formation of energy band diagram, intrinsic carrier concentration, donors and acceptors, nondegenerate and degenerate semiconductors, mobility, carrier diffusion, current density, recombination processes, continuity equation.

**Junctions:** p-n junction diode, thermal equilibrium condition, depletion region, depletion capacitance current voltage characteristics and temperature effect, charge storage and transit behavior, junction breakdown.

### UNIT II

**Transistors:** Bipolar transistor, fabrication techniques of bipolar transistor, transistor action, static characteristics of bipolar transistor, frequency response and switching of bipolar transistor, heterojunction bipolar transistor.

**Heterostructures:** Metal semiconductor contacts, basic characteristics, Schottky barrier, ohmic contact, MOS structure, MIS diode, operation and its characteristics, MOSFET scaling, scaling effects, charge coupled device (CCD). Quantum and Nanoelectronics (basic ideas) Review of physics and properties of semiconductor, p-n junction diode, bipolar transistor, Metal semiconductor contacts, MIS diode and CCD, Scaling effects, Hetero junction and hetero structure devices, MOSFET Modeling, Quantum and Nanoelectronics.

### UNIT III

**MEMS AND NEMS:** Overview, working principle of sensors and microactuation, scaling laws, **materials for MEMS**, active substrate materials, polymers as MEMS and NEMS materials, Consideration for microfabrication materials, LIGA process, microsystem packaging, die, device and system level packaging, interfaces in microsystem packaging for different application, signal mapping and transduction, micro system design consideration, process design, mechanical design, mechanical design using Fem, design considerations for optical, fluidic, RF and bio MEMS, overview of CAD tools for MEMS and NEMS design and simulation.

### Books and Suggested Readings:

1. *Semiconductor Devices, 2<sup>nd</sup> edition* by S.M. Sze
2. *Introduction to Semiconductor Materials and Devices* by S.M. Tyagi
3. *Nanoelectronics & Nanosystems: From Transistor to Molecular & Quantum Devices* by Karl Goser, Jan Dienstuhl and others.
4. *Nano Engineering in Science & Technology : An introduction to the world of nano design* by Michael Rieth.
5. *Enabling Technology for MEMS and nano devices* -Balles, Brand, Fedder, Hierold.
6. *Optimal Synthesis Methods for MEMS-* G. K. Ananthasuresh
7. *MEMS & MOEMS Technology and Applications-* P. Rai Choudhury
8. *Processing Technologies-* Gandhi

## MNT6205 CARBON NANOTUBE, ITS FUNCTIONALIZATION AND NANOFLUIDICS

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions/problems covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least



one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

#### UNIT I

##### Structure of carbon nanotubes

**Preparation of Carbon Nano-Tubes (CNT):** CVD, arc discharge and other methods of preparation

**Properties:** Electrical, Optical, Mechanical and Vibrational properties.

#### UNIT II

**Applications:** Field emission, Fuel Cells, Display devices

**Functionalization of CNTs:** Functionalization of Carbon Nanotubes, Reactivity of Carbon Nanotubes; Covalent Functionalization -Oxidative Purification; Defect Functionalization -Transformation and Modification of Carboxylic Functionalization like Amidation, Thiolation, Halogenations, Hydrogenation, Addition of Radicals, Addition of Nucleophilic Carbenes, Sidewall Functionalization through Electrophilic Addition, Cycloadditions, Carbenes Addition, Addition of Nitrenes, Noncovalent Exohedral Functionalization, Endohedral Functionalization

#### UNIT III

**Introduction to nanofluidics:** Continuum governing equations, boundary conditions, Couette and Poiseuille flow, thin films equations, flow in nanotubes.

**Transport Phenomena:** Fick's law, hydrodynamic equations, application to confined fluids at nanoscale.

**Surface tension:** static and dynamic contact angle, surface energies, capillary flows.

**Microfluidics devices:** Microarray chips as well componentry, pump, mixers, valves, lithography, etching, photopolymerization, multilayer soft lithography.

#### Books

1. *Synthesis functionalization and surface treatment of nanoparticles* - Marie Isabelle Baraton
2. *Physical properties of Carbon Nanotube* - R Satio
3. *Applied Physics Of Carbon Nanotubes : Fundamentals Of Theory, Optics And Transport Devices* - S. Subramony & S.V. Rotkins
4. *Carbon Nanotubes: Properties and Applications*- Michael J. O'Connell
5. *Nanotubes and Nanowires*- CNR Rao and A Govindaraj, RCS Publishing
6. *Carbon Nanotubes: Multifunctional Materials* – Ed. Prakash R. Somani and M. Umeno, Applied Science Innovations Pvt. Ltd., India
7. *Physical chemistry of surfaces* by Arthur W. Adamson and Alice P. Gast (John Wiley and Sons, 1997)
8. *Fundamentals of microfabrication : The science of miniaturization* by Mare J.Madou (CRC Press 2002)
9. *Colloidal dispersion* by W.B.Russel, D.A.Saville, W.R.Schwalter (Cambridge University Press 1992)  
*Statistical Mechanics* by D.A.McQuaire (New York: Harper and Row: 1976)

### MNT7101 SUPRAMOLECULAR AND SURFACE CHEMISTRY

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions/problems covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

#### UNIT I

Basics of Supramolecular Chemistry

Non-covalent interactions; Definitions in supramolecular chemistry; Host – Guest chemistry; Complexation of cations, anions & neutral molecules (crown ethers template effect).

#### UNIT II

Supramolecular Chemistry: Structures & Design

Catenanes, rotaxanes; Molecular switches & devices; Fullerenes, graphene, carbon nanotubes; Materials for non-linear optics ( $\pi$  – conjugated donor – acceptor systems);  $\pi$  – conjugated polymers (synthesis & conducting properties); Supramolecular design strategy & nanotechnology

#### UNIT III

Surface Chemistry

Colloidal state: Determination of size of colloidal particles; Types of surfactants: Anionic, cationic, gemini, zwitterionic & non-ionic (non-ionic); Theory of surfactants; CMC – Effect of chemical structure, temperature; Kraft temperature; Emulsions & gels

#### UNIT IV

Phase Behaviour of Concentrated Surfactant Systems

Micelle type, Micellar growth, Micellar solution saturation; Structure of liquid crystalline phases; Surfactant geometry & packing; Introduction to microemulsion.

#### Recommended texts:

1. *Surfactants and Polymers in Aqueous Solution* by K. Holmberg, B. Jonsson, B. Kronberg, B. Lindman, Wiley – England 2004.
2. *Dynamics of Surfactant Self-assemblies* by Raoul Zana (Ed.), Taylor & Francis.
3. *Supramolecular Chemistry* by J.W. Steed, J.L. Atwood, Wiley.

### MNT7102 NANOCOMPOSITES: STRUCTURE PROPERTIES AND PERFORMANCE

The question paper for end-semester examination will consist of seven questions of equal marks, viz. 15. The first question will be compulsory and will consist of several short questions/problems covering the entire syllabus. The rest of the questions shall be distributed evenly over the whole syllabus, such that there is at least one question from each unit. The question paper may contain questions which are partly from one unit and partly from another. The candidates will attempt five questions in all, including the compulsory question.

The books indicated as text-book(s) are suggestive of the level of coverage. However, any other book may be followed.

#### UNIT I

**Introduction** to composites- Various types Macro composites MMC, PMC, CMC, Blends, Need and importance.

**Particulates and Fillers:** 3-D Nanosilica particles, 2-D Nanotubes, 1-D Nanoclay

**Properties of Virgin Materials-** Need to modify, Mechanical, Electrical, Chemical Physical.

#### UNIT II

**Novel properties imbibed:** improved barrier properties, fire resistance, and strength

**Different Polymer Nanocomposites:** PU/Clay, Rubber-Clay Nanocomposites, PU

**Nanosilica, PET/Clay, PP Silica**

#### UNIT III

**Processing** of Nanocomposites

**Rheology** of nanocomposites coatings

#### UNIT IV

**Characterisation** of Nanocomposites: Techniques to analyse and study e.g HRTEM, DMTA

**Potential Applications-** Packaging, Biodegradable, Medical/Pharmaceutical, Coatings

**Latest Research** findings

#### Books and suggested readings

1. *Nanocomposite thin films & coatings: Processing, properties & Performance* by Sam Zhang & Nasar Ali, World Scientific
2. *Polymer Nanocomposites* by Yiu-Wing Mai & Zhongzhen Yu, CRC
3. *Polymer Nanocomposites: Synthesis, Characterization, and Modeling* (Acs Symposium Series) (Hardcover) by Ramanan Krishnamoorti (Editor) and Richard A. Vaia (Editor), An American Chemical Society Publication (2001)
4. *Polymer-Layered Silicate and Silica Nanocomposites* by Y.C. Ke and P. Stroeve, Elsevier Science (2005)
5. [http://www.nsti.org/Nanotech2005/workshops/polymer\\_nanotechnology.html](http://www.nsti.org/Nanotech2005/workshops/polymer_nanotechnology.html)
6. Reference Research Articles/papers from Journals

#### Additional Recommended texts & References

1. Nanochemistry: A Chemical Approach to Nanomaterials – Royal Society of Chemistry, Cambridge UK 2005.
2. Nanocomposite science and technology – P.M. Ajayan, L.S. Schadler, P.V. Braun, Wiley, New York.
3. Active Metals: Preparation, characterization, applications – A. Furstner, Ed., VCH, New York 1996.
4. Characterization of nanophase materials – Z.L Wang (ed), Wiley-VCH, New York 2000.
5. Nanoparticles: From theory to applications – G. Schmidt, Wiley Weinheim 2004.

6. Nanostructured Silicon – based powders and composites – Andre P Legrand, Christiane Senemaud, Taylor and Francis, London New York 2003.
7. Polymer – clay Nanocomposite – T.J. Pinnayain, G.W. Beall, Wiley, New York 2001.
8. Block Co-polymers in Nanoscience – Massimo Lazzari, Guojun Liu, Sebastien Lecommandoux, Wiley, New York 2007.

### **MNT7103 and MNT7201 PROJECT and DISSERTATION**

Each student will be required to work on major project approved by department faculty that will span third and fourth semesters during which periodic progress reports will be monitored. At the end of third semester, project progress will be evaluated by department faculty.

At the end of IV semester, the student will submit the thesis based upon his/her project work

### **MNT 7202 SEMINAR**

Each student will be required to *present his/ her project work/ dissertation* in the form of a seminar.

## **LABORATORY COURSES :**

### **MNT 6207 SCIENTIFIC COMPUTATION AND SIMULATION- II**

Twelve open ended experiments based on Fortran, Mathematica or C++ and on numerical methods.

#### **Books and Suggested Readings:**

1. *Numerical Methods for Scientific and Engineering Computation*, M. K. Jain, S. R. K. Iyengar and R. K. Jain, Wiley Eastern
2. *Handbook of Theoretical and Computational Nanotechnology*, Eds. Michael Rieth and Wolfram Schommers, 2006
3. *Introductory Computational Physics* Andi Klein and Alexander Godunov (Cambridge)
4. *Handbook of Mathematica*
5. *Modelling Molecular Structures* by Allan Hinchliffe (Wiley)

### **MNT 6106: LABORATORY I**

Each student is required to perform the following open-ended experiments.

1. Hall effect
2. Four probe conductivity
3. ESR measurements
4. XRD setup
5. Preparation of nano-oxides by sol-gel method and their characterization
6. Determination of Iron spectrophotometrically by o-phenanthroline method.
7. Study of Langmuir and Freudlich adsorption isotherms for adsorption of oxalic acid on activated charcoal.
8. Qualitative and quantitative analysis of carbohydrates
9. Isolate and quantitative Estimation of protein from biological source.

### **MNT 6206: LABORATORY II**

Each student is required to perform the following open-ended experiments.

1. Thin film setups
2. Characterization based on FTIR
3. Production of nanoparticles by chemical route
4. Size determination of microbes/ nanoparticles
5. To measure the electrical properties of biological tissues. (3 sessions)

### **MNT 7104 LABORATORY III**

1. XRD
2. SEM
3. STM
4. TEM
5. Carbon based nano material production
6. Mass spectrometry
7. Fluorescence microscope