SCHEME OF STUDY AND EXAMINATION

I Semester

Subject Code	Name of the Subject	Teaching hours/week		Duration of Exam in Hours	Marks for		Total Marks	Credits
		Lecture	Practical/ Field Work/ Assignment/ Tutorials		I.A.	Exam		
14INT11	Applied Mathematics	4	2	3	50	100	150	4
14INT12	Nanomaterials	4	2	3	50	100	150	4
14INT13	Nanoelectronics	4	2	3	50	100	150	4
14INT14	Nanobiotechnology	4	2	3	50	100	150	4
14INT15X	Elective – I	4	2	3	50	100	150	4
14INT16	Lab Component–I	--	3	3	25	50	75	2
14INT17	Seminar	--	3	--	25	--	25	1
	Total	**36**		**15**	**300**	**550**	**850**	**23**

Elective – I

14INT151	Simulation and modeling
14INT152	Nanotechnology in food and Agriculture
14INT153	Nanocomposites and Applications

Note:

- Each theory paper will be of 4 credits. There will be 4 hours of lecture per week for each paper and 2 hours of Practical/ Field Work/ Assignment/ Tutorials/Miniproject for each paper including the elective paper.
- Following activities are to be assigned to students under 2 hours Practical/ Field Work/ Assignment/ Tutorials for the papers mentioned.
  14INT11 Applied Mathematics: Practical classes on Simulation.
  14INT12 Nanomaterials: Assignment to each student on advanced topic in Nanomaterials and Group discussion
  14INT13 Nanoelectronics: Assignment to each student on advanced topic in Nanoelectronics and Group discussion
  14INT14 Nanobiotechnology: Assignment to each student on advanced topic in Nanobiotechnology and Group discussion.
  14INT15X Elective I: Mini project to be assigned to each student on the elective subject he/she has opted.
- Seminar topics on recent advances in the subjects of the study to be assigned to the students.

II Semester

Subject Code	Name of the Subject	Teaching hours/week		Duration of Exam in Hours	Marks for		Total Marks	Credits
		Lecture	Practical/ Field Work/ Assignment/ Tutorials		I.A.	Exam		
14INT21	Synthesis and Processing Techniques	4	2	3	50	100	150	4
14INT22	Characterization Techniques	4	2	3	50	100	150	4
14INT23	MEMs and NEMs	4	2	3	50	100	150	4
14INT24	Nanomaterials and Energy Systems	4	2	3	50	100	150	4
14INT25X	Elective-II	4	2	3	50	100	150	4
14INT26	Lab Component– II		3	3	25	50	75	2
14INT27	Seminar	--	3	--	25	--	25	1
	** Project Phase – I (6 week duration)							
	Total	**36**		**15**	**300**	**550**	**850**	**23**

Elective – II

14INT251	Advanced Materials
14INT252	Biosensors and Instrumentation
14INT253	Micro and Nanofluidics

**** Between the II Semester and III Semester, after availing a vocation of 2 weeks.**

Note:

- Each theory paper will be of 4 credits. There will be 4 hours of lecture per week for each paper and 2 hours of Practical/ Field Work/ Assignment/ Tutorials for each paper including the elective paper.
- Following activities to be done under 2 hours Practical/ Field Work/ Assignment/ Tutorials for the papers mentioned.
  14INT21 Synthesis and Processing Techniques: Practical classes on Synthesis and Processing Techniques.
  14INT22 Characterization Techniques: Practical classes on Characterization Techniques
  14INT23MEMs and NEMs: Practical classes on MEMs and NEMs.
  14INT24 Nanomaterials and Energy Systems: Practical classes on Nanomaterials and Energy Systems.
  14INT25X Elective II: Mini project to be assigned to each student on the elective subject he/she has opted.
- Seminar topics on recently published articles to be assigned to the students.

III Semester

Subject Code	Subject	Teaching hours/week		Duration of Exam in Hours	Marks for		Total Marks	Credits
		Lecture	Practical/ Field Work/ Assignment/ Tutorials		I.A.	Exam		
14INT31	Seminar/Presentation on internship (After 8 weeks from date of commencement)	--	--	--	25	--	25	1
14INT32	Report on internship	--	-	--	--	75	75	15
14INT34	Evaluation of Project Phase – I	–	--	--	--	50	50	4
Total		**--**		**--**	**25**	**125**	**150**	**20**

IV Semester

Course Code	Subject	Teaching hours/week		Duration of the Exam in Hours	Marks for		Total Marks	Credits
		Lecture	Practical/ Field Work/ Assignment/ Tutorials		I.A.	Exam		
14INT41	Nanotechnology and Environment	4	2	3	50	100	150	4
14INT42X	Elective – III	4	2	3	50	100	150	4
14INT43	Evaluation of Project Phase – II	-	3	-	25	-	25	1
14INT44	Evaluation of Project work – III	-	3	-	25	-	25	1
14INT45	Project work evaluation and Viva-voce	-	17	3	–	100+100	200	18
	Total	**23**		**09**	**100**	**400**	**550**	**28**
Grand Total Marks (I to IV Sem.) : 2400; 94 credits								

Elective – III

14INT421	Nanotechnology in Drug Delivery
14IN422	Nanophotonics
14INT423	Emerging Computing Techniques

Note:

- Each theory paper will be of 4 credits. There will be 4 hours of lecture per week for each paper and 2 hours of Practical/ Field Work/ Assignment/ Tutorials for each paper including the elective paper.
- Following activities to be done under 2 hours Practical/ Field Work/ Assignment/ Tutorials for the papers mentioned.
  14INT41 Nanotechnology and Environment: Assignment to each student on advanced topic in Nanotechnology and Environment.
  14INT42X Elective III: Assignment to each student on advanced topic in the elective subject which he/she opted.

SCHEME OF EVALUATION

Following is the model distribution of marks for Internal Assessment and term end examination. At a glance, the model includes theory, lab component, seminar and project work marks.

The following is the scheme which will be followed for the assessment of marks for theory, lab component, seminar and project work irrespective of the credit associated with each paper. Each theory paper carries 150 marks. 50 marks are allotted to internal assessment and remaining 100 marks for Semester End Examinations. Out of 50 marks for internals, 30 marks will be allotted to theory tests (average of two best among the three tests conducted in a semester) and remaining 20 marks for assessment of the Practical/ Field Work/ Assignment/ Tutorial work assigned.

Lab Component is of 75 marks in which 25 marks are for internal assessment and 50 marks for semester end lab examination.

NOTE:

- Project Phase – II:16 weeks duration. 3 days for project work in a week during III Semester. Evaluation shall be taken during the first two weeks of the IV Semester. Total Marks shall be 25.
- Project Phase – III :24 weeks duration in IV Semester. Evaluation shall be taken up during the middle of IV Semester. At the end of the Semester Project Work Evaluation and Viva-Voce Examinations shall be conducted. Total Marks shall be 250 (Phase I Evaluation:25 Marks, Phase –II Evaluation: 25 Marks, Project Evaluation marks by Internal Examiner(guide): 50, Project Evaluation marks by External Examiner: 50, marks for external and 100 for viva-voce). Marks of Evaluation of Project: I.A. Marks of Project Phase – II & III shall be sent to the University along with Project Work report at the end of the Semester. During the final viva, students have to submit all the reports.
- The Project Valuation and Viva-Voce will be conducted by a committee consisting of the following:
  a) Head of the Department (Chairman)
  b) Guide
  c) Two Examiners appointed by the university. (Out of two external examiners at least one should be present)

APPLIED MATHEMATICS

Sub Code :	**14INT11**	**IA Marks**	**: 50**
Hrs/ Week :	**04**	**Exam Hours**	**: 03**
Total Hrs. :	**50**	**Exam Marks**	**: 100**

Course Objectives

The Student will learn different mathematical concept that can be used in finding solutions to many engineering problems and in formulating mathematic models to represent engineering applications.

Course Content

1. Linear Algebra: Definition of a matrix, types of matrices, matrix operations such as addition, subtraction, scalar and vector multiplication, matrix characteristics like rank, transpose, trace, determinant, inverse of a matrix: identity matrix method and cofactor method of finding the inverse of a matrix, rules for binary operations, unary operation, linear systems of equations, solutions of linear equations by Gauss elimination and Cramer's rule.

Numerical Solutions of Algebraic and Transcendental Equations: Fixed Point Iteration, Bisection Method, False Position or Regular Falsi Method, Newton-Raphson Method, Secant Method, Muller's Method, improved Newton Method. **12 Hours**

2. System of Equations: Simultaneous equations in matrix form, consistency of equations, types of solutions, methods of solving simultaneous equations: Gauss elimination method, Gauss-Siedel method, Inverse matrix method, Giraff'S root square method, determinant method, Triangular Systems and Back Substitution, Gauss-Jordan Elimination and Pivoting, Tri-Diagonal Matrices, Inverse Matrix, LU Factorization, Cholesky, Jacobi, Pivoting Methods, Iterative Refinement, Linear Programming-Simplex Method.

8 Hours

3. Eigen Value Problems: Definition, Eigen values and Eigen vectors, Theorems of Eigen values and Eigen vectors, methods of solving Eigen value problems: Characteristic equation method, Iterative method. Some applications of Eigen value problem.

Orthogonality and Least Squares: Inner product, length and orthogonality, orthogonal sets, Orthogonal projections, The Gram-schmidt process, Least Square problems, Inner product spaces.

12 Hours

4. Solution of Ordinary Differential Equations: Euler's Method, Taylor Series Method, Runge-Kutta Method, Runge-Kutta-Fehlberg Method, Adams-Bashforth-Moulton Method, Milne-Simpson's Method, Predictor-Corrector Methods, Galerkin's Method.

Curve Fitting: Least Squares Lines, Least Squares Polynomials, Nonlinear Curve Fitting, Logistic Curve, FFT and Trigonometric Polynomials, Conic Fit, Circle of Curvature.
10 Hours

5. Numerical Integration: Midpoint Rule, Newton-Cotes Integration, Trapezoidal Rule for Numerical Integration, Simpson's Rule for Numerical Integration, Simpson's 3/8 Rule for Numerical Integration, Adaptive Simpson's Rule, Gauss-Legendre Quadrature, Cubic Spline Quadrature, Monte Carlo Pi, Monte Carlo Integration, 2D Trapezoidal and Simpson Rules. **8 Hours**

Text Books:

1) Steven C.Chopra, Raymond P.Canale "Numerical Methods for Engineers", 4th Edition, Tata McGraw Hill.
2) Pervez Moin "Application of Numerical methods to Engineering".
3) David. C. Lay, "Linear Algebra and its Applications" -3rd Edition, Pearson Education.

Reference Books:

1) M. K. Jain, S.R.K. Iyengar, R K. Jain "Numerical Methods for Scientific and Engineering, Computation". NEW AGE INTERNATIONAL Publishers.
2) S.S.Sastry "Numerical Analysis for Engineers"-Tata Mcgraw Hill Edition.
3) B.S. Grewal " Higher Engineering Mathematics" 42nd Edition, Khanna Publishers

Course Outcomes:

The Student will be able to

1. Model some simple mathematical models of physical Applications.
2. Find the roots of polynomials in Science and Engineering problems.
3. Differentiate and integrate a function for a given set of tabulated data, for Engineering Applications.

NANOMATERIALS

Sub Code :	**14INT12**	**IA Marks**	**: 50**
Hrs/ Week :	**04**	**Exam Hours**	**: 03**
Total Hrs. :	**50**	**Exam Marks**	**: 100**

Course Objective

This course introduces various concepts of Nanoscience and nanotechnology. Understand the relation between size and properties of Nanomaterials. To learn the importance of potential Nanomaterials

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Course Content

1. Introduction to nanoscience and nanotechnology: History, background scope and interdisciplinary nature of nanoscience and nanotechnology, scientific revolutions. Definition of Nanometer, Nanomaterials, and Nanotechnology. Concepts of nanotechnology - size dependent phenomena, surface to volume ratio, atomic structure, molecules and phases, energy at the nanoscale molecular and atomic size.

10 Hours

2. Classification of nanostructures - Zero dimensional, one-dimensional and two dimensional nanostructure materials. Clusters of metals, semiconductors, ceramics and nanocomposites. Size effect on shapes, Quantum dots, Nanorods, nanowires, nanotubes, nanosheets, nanocones, Nanotetrapods, Nanoflowers, nanobrushes, nano and mesopores, Core-Shell nanoparticles, misnomers and misconception of nanotechnology, importance of nanoscale materials and their devices

10 Hours

3. Properties of Nanomaterials -1: Mechanical properties, Nano size effect on strength, fracture toughness and fatigue behavior. Bulk Properties of Materials, electrical conductivity, Dielectric properties, Thermal properties, thermal conductivity, heat capacity. Magnetic properties, Magnetic materials, domains in Magnetic materials.

10 Hours

4. **Properties of nanomaterials -2:** Electronic structure of Nanomaterials, magic numbers, Fermi surface, Size effect on Electron-Phonon Coupling, Size effect on physical properties. Optical properties, Optoelectronic properties of bulk and nanostructures, relation between optical properties and electronic structure of nanomaterials – Catalytic property Catalysis by Gold Nanoparticles

10 Hours

5. T**ypes of nanomaterial:** Metal nanoparticles, Ceramics nanomaterials, Semiconductor nanoparticles, Metal oxides nanoparticles, Carbon based nanostructures, Graphene, Carbon Nanotubes, Fullerenes, Importance of these nanomaterials and their applications.

10 Hours

Text Books

1. Edward L. Wolf, "Nanophysics and Nanotechnology - An Introduction to Modern Concepts in Nanoscience" Second Edition, John Wiley & Sons, 2006.
2. M.S. Ramachandra Rao, Shubra Singh, Nanoscience and Nanotechnology: fundamentals to Frontiers, Wiley 2013
3. Nanostructures and Nanomaterials synthesis, properties and applications, g. Cao, Imperial College press 2004.

References

1. Masuo Hosokawa, Kiyoshi Nogi, Makio Naito, Toyokazu Yokoyama **Nanoparticle Technology Handbook,** Elsevier Science, 2007
2. Nanotechnology – Basic Science & Emerging Technologies, Chapman & Hall/CRC 2002
3. Nanomaterials – A. K. Bandyopadhyay, New Age International Publishers, 2nd Edition, 2010

Course Outcomes:

The Student will be able to

1. Understand the structure-property relationships in nanomaterials as well as the concepts, that are different from bulk counterpart.
2. An ability to demonstrate a systematic knowledge of the range and breadth of application of nanomaterials.
3. Review critically the potential impact, in all classes of materials and nanostructure.

NANOELECTRONICS

Sub Code	**:**	**12INT13**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objectives

The students will learn underlying device physics and process technologies involved in modern day electronic devices and appreciate the complexities in scaling down the electronic devices in the future.

Course Content

1. Introduction to electronics: Classification of solids, energy levels, intrinsic and extrinsic semiconductor, conduction in metals and semiconductors, Fermi-Dirac carrier statistics, Mobility dependence on temperature and doping, Conductivity, Velocity saturation, Diffusion and Drift current, Fermi level and Quasi Fermi level, Semiconductor diodes: Diode under forward bias condition, Diode under reverse bias, Avalanche and Zener breakdown, PIN diode, Tunnel diodes, photo diode, Light Emitting Diode, Photovoltaics,

Metal-semiconductor junctions, ohmic contacts and schottky diodes, schottky barrier height, Ideal schottky theory and effect of surface states. **10 Hours**

2. BJT and MOSFETs: Emitter efficiency, Base transport factor, Current gain, I-V characteristic in cut-off, linear and saturation regions, Transistor breakdown, hetrojunction Bipolar Transistor (HBT) MOSFETs : MOS capacitor, Depletion, Inversion and accumulation, Solution of Poisson’s equation for MOS capacitor, Derivation of threshold voltage, CV characteristics, High frequency And Low frequency characteristics, Effect of oxide charges and interface trapped charges, Charge Coupled Device (CCD) MOS transistor, Derivation of I-V characteristics, Pinch off, Channel length modulation, Body bias effect.

10 Hours

3. Nanoscale MOSFETs: MOSFET as digital switch, Propagation delay, Dynamic and static power dissipation Moore’s law, Transistor scaling, Constant field scaling theory, Constant Voltage Scaling, Generalized scaling, Short channel effects, Reverse short channel effect, Narrow width effect, Subthreshold conduction leakage, Subthreshold slope, Drain Induced Barrier Lowering, Gate Induced Drain Leakage, Design of NanoMOSFET, Halo implants, Retrograde channel profile, Shallow source/drain extensions, Twin well CMOS process flow, Gate Tunneling : Fowler Nordheim and Direct Tunneling, High k gate dielectrics, Metal gate transistor, Transport in Nanoscale MOSFET, Ballistic transport, Channel quantization.

10 hours

4. Advanced transistors: Silicon on Insulator (SOI) devices, Partially depleted and Fully depleted SOI Ultrathin body transistor, Double gate transistor, FinFET, Surround gate transistor, Silicon Nanowire transistor, Strained silicon transistor, Germanium MOSFETs, III-V compound semiconductor based transistor, High Electron Mobility Transistor (HEMT), CNT transistor, Graphene transistor, Transition-Metal Dichalcogenide (TMD) transistor. **10 hours**

5. Interconnects technology and Reliability: Multilevel metal interconnects in CMOS technology, Interconnect RC delay trend with scaling, Scaling of metal interconnect capacitance and resistance, Aluminum interconnect versus Copper interconnect, Dual Damascene process, Low k dielectrics, Stress migration and Electromigration, Gate oxide reliability, Hot carrier reliability, CNT interconnects, Optical interconnect technology. **10 hours**

Text Books:

1. Streetman and Banerjee, Solid State Electronic Devices, Prentice-Hall
2. Yaun Taur and Ning, Fundamentals of Modern VLSI Devices, Cambridge University Press
3. Kwok Ng and S. M. Sze, Physics of Semiconductor Devices, Wiley

References:

1. International Technology Roadmap for Semiconductors (ITRS), http://www.itrs.net/

2. Review papers from recent literature

Course Outcomes:

The students will be able to

1) Design transistors with dimensions less than 100 nm to produce required performance from the device
2) Design the process flow required to fabricate state of the art transistor technology.
3) Analyze the requirements for new materials and device structure in the future technologies.

NANOBIOTECHNILOGY

Sub Code	**:**	**14INT14**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objectives

This course provides fundamental aspects of biotechnology. It also provides platform to understand the interaction of nanostructures and biomolecules, application of various nanomaterials in biological application.

Course Content

1. **Fundamentals of Biotechnology:** Basic terms in biotechnology, recombinant DNA technology, genetic engineering, gene cloning. Development of nanobiotechnology, timelines and progress. Basics of cell orgenells. Biomacromolecules- carbohydrates, lipids, proteins and nucleic acids, PHA, cyanophcin inclusion, magnetosome, alginates, bacteriophages, S-layer protein, bacteriorhodpsin. Biological building blocks; Sizes of building blocks and comparison with nanostructures.

   12 hours

2. **Nanostructures:** DNA and protein based nanostructures, DNA origami, DNA nanotubes, polypeptide nanowire and protein nanoparticles, SAM, biological nanomotor. Nanoconjugates: DNA-gold nanoconjugates. DNA based nanoelectronics: immobilization of DNA on substrates, probing the electronic properties of single DNA molecules. Manipulation of DNA on metal surfaces.

   10 hours

3. **Interaction between biomolecules and nanoparticle surface**: Different types of inorganic materials used for the synthesis of hybrid nano-bio assemblies, Application of nano in biology, nanoprobes for Analytical Applications - A new methodology in medical diagnostics and Biotechnology, Current status of Nanobiotechnology, Future perspectives of Nanobiology.

   10 hours

4. **Applications of nanomaterials:** Drug delivery and gene delivery, Nanobiochips, biosensors. Nanomaterials in bone substitutes and dentistry. Polymeric nanofibres-tissue engineering, smart capsules, microemulsions, nano based cancer therapy, nanorobotics. Lotus leaf as a model self-cleansing system. Diatoms as example for silicon biomineralization. Biomechanical strength properties of Spider silk.

   10 **hours**

5. **Photoinduced Electron Transport in DNA:** Electronic Devices Based on DNA Architecture, DNA Nanowires, Charge Transport, DNA-Based Nanoelectronics, Electrical Manipulation of DNA on Metal Surfaces, Nanostructured Biocompartments, DNA-Gold nanoconjugates.

   08 Hours

TEXT BOOKS

1. Nanobiotechnology: Bioinspired devices and materials of the future by Oded Shoseyov, Ilan Levy. Humana Press 2010.
2. Bionanotechnology - Global Prospects by David E. Reisner, Taylor & Francis Group, LLC, 2009.
3. Nanotechnology in Drug Delivery by Melgardt M. deVilliers, Pornanong Aramwit, Glen S. Kwon, Springer-American Association of Pharmaceutical Scientists Press 2009.

References

1. T. Pradeep , "*NANO The Essential , understanding Nanoscience and Nanotechnology".* Tata McGraw-Hill Publishing Company Limited, 2007.

2.Nancy A. Monteiro-Riviere, C. Lang Tran Nanotoxicology: Characterization, Dosing and Health Effects Published:July 25, 2007 by CRC Press

Course Outcomes:

Students will be able to

1. Demonstrate knowledge of biotechnology to understand Nanobiotechnology.
2. Analyze the interaction of various biomolecules and nanostructures.
3. Design and develop nanostructures and biomolecules for various biological applications.

Elective - I

SIMULATION AND MODELLING

Sub Code	:	**14INT151**	**IA Marks**	:	**50**
Hrs/ Week	:	**04**	**Exam Hours**	:	**03**
Total Hrs.	:	**50**	**Exam Marks**	:	**100**

Course Objective:

The course gives a fundamental understanding of various simulation and modeling techniques used in nanotechnology and engineering analysis.

Course Content

1. Physical basis of quantum mechanics: Experimental background, inadequacy of classical physics, summary of principal experiments and inferences, Uncertainty and complementarity. Wave packets in space and time, and their physical significance.
Schrodinger wave equation: Development of wave equation: One-dimensional and extension to three dimensions.

Some exactly soluble Eigen value problems: One dimensional: Square well and rectangular step potentials, Rectangular barrier, Harmonic oscillator. Three dimensional: Particle in a box, Particle in spherically symmetric potential, Rigid rotator, Hydrogen atom.

10 Hours

2. Quantum mechanics of atoms and molecules: Hamiltonian and Wave functions-orbital approximation for multi-electron atoms-Pauli's Anti-symmetry principle, Born-Oppenheimer approximation, MO theory, LCAO approximation.

Approximation methods: Necessity of approximate methods, the variation method, Perturbation method.
Quantum Mechanical methods - Hartree Fock, Density Functional Theory, Configuration Interaction, Tight Binding, MNDO. Force Fields methods - Energy terms: valence, van der Waals, Coulomb. Functional forms, Dreiding, UFF. Charge transfer QEq, NB Cutoffs, Splines. Minimization: steepest descent, conjugate gradients, FP.

10 Hours

3. Molecular Dynamics simulations - NVE ensemble: Newton's Equations, Verlet algorithms, time step. Velocity initialization (Boltzmann), Equilibration, Anneal, Quench. Analysis: fluctuations, Kubo, Free Energy Pert Theory. NVT ensemble, NPT ensemble, Quantum Hopping MD. Monte Carlo methods – Introduction, Integration, Simulation, Random Walk, Percolation, Ising Model, Markov, Metropolis, RIS, CCBB. Solvation Methods - PB, QM, MD, MC; SGB, AVGB.

10 Hours

4. Computational Modelling of Nanoparticles: Introduction, Benefits of Computer Science for nanotechnology, modelling at different scales – electronic, atomistic, meso and continuum. Concept

of computational modelling of nanostructures, computational control of matter through modelling – empirical and Abinitio potentials, molecular dynamics simulation, monte carlo simulation, advantages and limitations of MDS and MCS.
Modeling of nanoparticles - electronic transport, mechanical properties, optical properties. Bionanoparticles and polymer nanocomposites. Opportunities and challenges in computer modelling of nanoparticles.

10 Hours

5. Modeling, design and simulation of NEMS and MEMS:

Introduction, Lumped Modeling of carbon nanotubes, design and simulation of carbon nanotubes–sugar design, sugar cube design and simulation and applications.

Lumped modeling of MEMS-sugar to sugarcube, Librarian, parameterization, simulation, static analysis, steady state analysis, sinusoidal analysis, transient analysis and optimization.

Design and simulation of NEMS and MEMS: Sugar model, sugar cube model, carbon nanotube model in sugar, first-order analysis of thermal actuator, thermo-mechanical response of the device, electro-thermo-actuator model.

10 Hours

Text Books

1. Jerrod H.Zar (1999) Biostatistical analysis by Prentice hall international Inc Press, London

2. "Handbook of theoretical and computational Nanotechnology" eds. Michael Rieth and wolfram schommers, 2006.

3. Computational physics, R. C. Verma, K. C. Sharma & P. K. Ahluwalia.

References

1. Computational Nanotechnology: Modeling and Applications with MATLAB® edited by Sarhan M. Musa

2. Computational Finite Element Methods in Nanotechnology

edited by Sarhan M. Musa

Course Outcomes:

The Student will be able to

1. Demonstrate the physical basis for quantum mechanics for nanotechnology
2. Quantum mechanical treatment for atomic and molecular

   aspects.

3. Simulation and modeling of various nanostructures and their properties

4. Design and modeling of NEMS and MEMS devices

NANOTECHNOLGY IN FOOD AND AGRICULTURE

Sub Code	**:**	**14INT152**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objective:

The course introduces application of nanotechnology in food packing, processing and agriculture field.

Course Content

1. Nanotechnology in Food: Introduction, Food Production, Antimicrobial Functionality, Visual Indicators, Physics and Structures in Food Bionanotechnology, Information and Communication Technology, Febrile Structures, Plate-Like Structures, Spherically Symmetric Structures, Bi-continuous Structures in Protein–Polysaccharide Systems, Gastronomy and the Nanodomain: Molecular Gastronomy, functional materials in food nanotechnology. 10 Hours

2. Nanotechnology in Agricultural: Introduction, Biosensors, Enzyme Biosensors and Diagnostics, DNA-Based Biosensors and Diagnostics, Radiofrequency Identification (RFID), Integrated Nanosensor Networks: Detection and Response, Precision Agriculture, Potential Changes in Farming Methods and Sustainable Agriculture.

Nanocapsule for delivery of pesticides: Nanosensors for monitoring of soil condition and plant growth, Nanoparticles to deliver DNA and growth hormones. Nanoparticles and CNT to enhance the growth rate of plants. 12 Hours

3. Advanced Processing Technologies: Introduction, Preservation Methods, Drying Techniques, Conventional methods and its limitation, infrared processing, di-electric heating, microwave processing, batch type and conveyor type systems, shelf-life, analysis of food characteristics. 8 Hours

4. Food Quality, Safety, and Security: Introduction, Improving Quality, Safety, and Security of Agricultural Production, Food Processing, Packaging and Distribution. Concerns about using Nanotechnology in Food Production. Reasons to Package Food Products, Physical Properties of Packaging Materials. Safety Assessment of Oral-Exposure Engineered Nanomaterials for Food Application. Toxicity aspects of nanofood, modification of nano materials to avoid toxic effect and commercial aspect. 10 Hours

5. Technology Issues: Life Cycle of Nanotechnology Food Products, Molecules in Foods Involved in Triggering Allergies, Food Structure, Processing, and Food Allergy, Impact of Nanoscale Structures on Allergenic Potential of Foods, Innovations in Food and Agriculture Nanotechnology. 10 Hours

Text Books

1. Lynn J. Frewer, Willem Norde, Arnout Fischer, Frans Kampers “Nanotechnology in the Agri-Food Sector” John Wiley and Sons,2010
2. S.Choudhary, ‘Applied Nanotechnology in Agriculture’, Arise Publication, 2011.

Course Outcomes:

The Student will be able to demonstrate the knowledge of nanotechnology and various nanomaterials in food and agricultural applications.

NANOCOMPOSITES AND APPLICATIONS

Sub Code	**:**	**12INT153**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objective:

Learn different types of Nanocomposites and Develop the knowledge of various nanostructures used in designing Nanocomposites. Applications Nanocomposites in industrial applications, the present course gives an overview of Nanocomposites and its application.

Course Content

1. Introduction to nanocomposites: Definition of composite material, Classification based on matrix and topology, Constituents of composites, Interfaces and Interphases, Distribution of constituents, Nano-composites. Advantage of composite materials, mechanical properties, Thermal, electrical and electronic and optical properties. Super hard nanocomposites-designing and mechanical properties - stress-strain relationship, toughness, strength, and plasticity.

08 Hours

2. Ceramic metal nanocompsites: Ceramic based nanoporous composites, metal matrix nanocomposites, natural nano-bioccomposites, bio-mimetic nanocompostes and biologically inspired nanocomposites, nanocompsites for hard coatings, DLC coatings, thin film naocomposites, modelling of nanocomposites, synthesis of various nanocomposites materials, sputtering, mechanical alloying.

08 Hours

3. Polymer nanocomposites: Introduction to polymer composites, Processing of nanoparticles, binding mechanisms in nanoparticles, dispersion of nanoparticles, and stabilization of nanoparticles. Processing and fabrication of polymer nanocomposites, Melt blending, solvent casting, In-situ polymerization, solution polymerization, template synthesis, high shear mixing. Homogeneous/heterogenous nucleation, plasma promoted nucleation. Polymer nanocomposites with structural, gas barrier and flame retardant properties, carbon fiber reinforced polymer composites, elastomer and thermoplastic elastomer nanocomposites for propulsion systems, water borne fire-retardant nanocomposites, hybrid composites for cosmetics, protective and decorative coatings.

14 Hours

4. Natural nanocomposite systems: Spider silk, bones, shells; organic–inorganic nanocomposite formation through self-assembly. Biomimetic synthesis of nanocomposite material; use of synthetic nanocomposites for bone teeth replacement. Bioactive nanocomoposites in bone grafting and tissue engineering, inorganic/polymer nanocomposites for dental restoration and bone replacement applications.

Bio ceramics for implant coating: Calcium phosphates-hydroxy epilates Ti6Al4V and other biomedical alloys, implant tissue interfacing-metal organic CVD-use of tricalcium phosphate-biomimetic and solution based processing- osteo porosis- osteo plastic, regeneration of bones by using bio compatible ceramics, bioninteractive hydro gels- PEG coating and surface modifications, PEG hydrogels patterned on surfaces- PEG based hydrogels.

14 Hours

5. Nanobiocomposites: Cell-substrate interaction, types of Nanomaterials for insitu composite formation, multifunctional namomaterials as biocompatible and bioactive components. Nanoscaffolds for tissue engineering- types of nanoscaffolds and formation techniques; advantages over macro/micro-structured surfacessk Nanomaterials for enhanced growth and differentiation of nerve cells, stem cells and osteoblasts.

6 Hours

Text Books

1. Nanocomposite science and technology by P.M.Ajayan, L.S. Schadler and P.V. Braun, Wiley-VCH GmbH Co. 2003.
2. Encyclopedia of Nanotechnology by H.S.Nalwa, American Scientific Publishers, 2003.
3. Metalopolymer nanocomposites, Ed A.D. Pomogailo and V.N.Kestelman, Springer-Verlag, 2005.
4. Composite materials, K.K. Chawala, 2nd ed., (1987) Springer-Verlag, New York.

References

1. Biomedical nanostructures by Kenneth E.Gonsalves, Craig R. Halberstadt, Cato T. Laurencin, Lakshmi S. Nair. John-Wiley & Sons, 2008.
2. Nanobiotechnology II: Edited by Chad A. Mirkin and Christof M. Niemeyer, Wiley-VCH, 2006.
3. Handbook of Biomineralization: Biomimetic and Bioinspired, Chemistry edited by Peter Behrens, Edmund Bäuerlein John-Wiley Sons, 2006.

Course outcome:

Students will be able to

1. Design different types nanostructures that are suitable to specific application.
2. Demonstrate a knowledge of polymer based nanocomposites and its applications.
3. Analyze the properties of polymer Nanocomposites and their behavior depending on the type of nanomaterials.

LAB COMPONENT

Sub Code	**:**	**14INT16**	**IA Marks**	**:**	**25**
Hrs/ Week	**:**	**03**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**36**	**Exam Marks**	**:**	**50**

Course Objective:

To learn the basic principles involved in nanoparticle synthesis.

To get hands on experience in synthesis of various nanoparticles. To design desired size and morphology controlled nanostructures.

1. Preparation of different concentration solutions and standardization
2. Verification of Beer Lombard's Law
3. Synthesis of metal (Au/Ag/Cu) nanoparticles by Chemical reduction method
4. Synthesis of metal oxide (TiO_2/ZnO/Fe_2O_3) nanoparticles by hydrothermal/solvothermal method
5. Synthesis of ceramic ($BaTiO_3$/$SrTiO_3$/Al_2O_3) nanomaterials by combustion process
6. Preparation of Polymer-Carbon nanostructure (CNT/Graphene/ Graphite oxide) Nanocomposites
7. Surface functionalization or modification of metal oxide nanoparticles with organic reagents
8. Synthesis of ZnS/MoS nanoparticles by solvothermal/ microwave solvothermal method
9. Thin film deposition by spray pyrolysis deposition (SPD)
10. Thin film deposition by Spin coating.
11. Thin film deposition using electrochemical workstation
12. Physical vapor deposition/sputtering deposition of metallic film on glass substrate

Course outcome

Students will be able to

Design the experiments and synthesize various nanoparticles. Prepare size and morphology controlled nanostructures.

SYNTHESIS AND PROCESSING TECHNIQUES

Sub Code	**:**	**14INT21**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objective

The course aims at providing overview of various synthesis techniques. Introduce different types of synthesis and processing techniques. Learn to choose suitable synthesis process and condition to get desired nanostructures.

Course Content

1. Introduction: Importance of Synthesis and Processing techniques, nanofabrication, Bottom-Up versus Top-Down; Top-down approach with examples. Stability and dispersion of Nanoparticles, Surface modification of inorganic nanoparticles by organic functional groups

08 Hours

2. Physical Methods: Ball milling synthesis, Arc discharge, RF-plasma, Plasma arch technique, Inert gas condensation, electric explosion of wires, Ion sputtering method, Laser pyrolysis, Molecular beam epitaxy and electrodeposition. Electro spinning, Physical vapor Deposition (PVD) – Chemcial vapour Deposition (CVD) - Atomic layer Deposition (ALD) – Self Assembly- LB (Langmuir-Blodgett) technique.

12 Hours

3. Chemical methods: Chemical precipitation methods- co-precipitation, arrested precipitation, sol-gel method, chemical reduction, photochemical synthesis, electrochemical synthesis, Microemulsions or reverse micelles, Sonochemical synthesis, Hydrothermal, solvothermal, supercritical fluid process, solution combustion process,4 spray pyrolysis method, flame spray pyrolysis, gas phase synthesis, gas condensation process, chemical vapor condensation. Fundamental aspects of VLS (Vapor-Liquid-Solid) and SLS (Solution-Liquid-Solid) processes – VLS growth of Nanowires – Control of the size of the nanowires – Precursors and catalysts – SLS growth – Stress induced recrystallization.

12 Hours

4. Biological methods: Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Natural and artificial synthesis of nanoparticles in microorganisms; Use of microorganisms for nanostructure formation, Role of plants in nanoparticle synthesis, synthesis of nanoparticles using proteins and DNA templates.

08 Hours

5. Lithography: Nanomanipulation and Nano lithography – Soft Lithography – Electron beam lithography, SEM based nanolithography, AFM based nanolithography, Ion beam lithography- Oxidation and metallization - Mask and its application - Deep UV lithography, X-ray based Lithography, Dip pen lithography. Self-assembly of Nanoparticles and Nanowires.

10 Hours

Text Books

1. Guozhong Cao, "*Nanostructures and Nanomaterials, synthesis, properties and applications",* Imperial College Press, 2004

2. M.S. Ramachandra Rao, Shubra Singh, Nanoscience and Nanotechnology: fundamentals to Frontiers, Wiley 2013.

3. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens.

Reference Books

1. Nanomaterials – A. K. Bandyopadhyay, New Age International Publishers, 2nd Edition, 2010
2. T. Pradeep , "*NANO The Essential , understanding Nanoscience and Nanotechnology".* Tata McGraw-Hill Publishing Company Limited, 2007.

3. C.A. Mirkin and C.M. Niemeyer, Nanobiotechnology- II, More Concepts and Applications, WILEY-VCH, Verlag Gmb H&Co, 2007.

4. David G. Bucknall. Nanolithography and patterning techniques in microelectronics, CRC Press,

Additional Readings

1. Hari Singh Nalwa - Encyclopedia of Nanotechnology.

2. Processing & properties of structural Naonmaterials by Leon L. Shaw (editor)

3. Chemistry of Nanomaterials : Synthesis, properties and applications by CNR Rao et.al.

4. Nanochemistry: A chemical approach to Nanomaterials Roayal Society of Chemistry, Ozin and Arsenault, Cambridge UK 2005,

5. Nanoparticles: From Theory to Applications, G.Schmidt, Wiley Weinheim 2004.

Course Outcome:

Students get an idea of various synthesis and processing techniques used to design desired nanostructure and size and morphology controlled nanostructure to get desired property. Students will be able have controlled synthesis of material for various application.

CHARACTERIZATION TECHNIQUES

Sub Code	**:**	**14INT22**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objective:

The course aims at providing overview of various characterization techniques. Analyze the data obtained from different techniques and evaluate size, structure, morphology and properties of nanomateirals.

1. **Basics of nanomaterial characterization;** elemental or compositional information, structural and microstructural information. **4 Hours**

2. **X-Ray based characterization:** Principles and applications of X-ray diffraction, powder (polycrystalline) and single crystalline XRD techniques; Debye-Scherrer equation to treat line broadening and strain induced in nanoparticles and ultra-thin films. Basics of structure refinement (Reitveld). Rotating anode and synchrotron based X-ray diffraction for probing structure. X-ray photoelectron spectroscopy – basic principle, instrumentation, X-ray absorption techniques: XANES, EXAFS. **14 Hours**

3. **Electron microscopy techniques:** Introduction, Principles and applications of Electron beam, Electron beam interaction with matter. Scanning electron microscopy (SEM/FESEM), transmission electron microscopy (TEM/HRTEM), Electron-diffraction, SAED**.** Scanning Probe Microscopy: Principles and applications, Atomic Force Microscope, Scanning Tunneling Microscope. **11 Hours**

4. **Spectroscopic techniques:** UV-VIS Spectrophotometers, IR/FTIR Spectrophotometers, Principles, operation and application for band gap measurements. Raman spectroscopy principles and applications. Optical microscope: Nanoparticle size measurement by Dynamic light scattering methods zeta potential. **10 Hours**

5. **Magnetic characterization:** Types of magnetic materials, Magnetic susceptibility, Curie-Weis plot for paramagnetic materials, Neel temperature, Curie temperature VSM and SQUID magnetometers – M vs H, M vs T, MH-loops.
   Electrical measurements: Cyclic Voltameter, IV, AC and DC electric measurements, impedance spectral information.

   11 Hours

Text Books

1. Characterization of Nanostructure materials by XZ.L.Wang
2. Instrumental Methods of Analysis, 7th edition- Willard, Merritt, Dean, Settle

3. *Scanning Probe Microscopy: Analytical Methods (NanoScience and Technology)- Roland Wiesendanger*

Reference Books

4. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition - Harold P. Klug, Leroy E. Alexander
5. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set**)**- David B. Williams and C. Barry Carter
6. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM **- Ray F. Egerton**

Course Outcome:

Students will be able to analyze the data from various characterization techniques used to evaluate nanomaterial structure, size, morphology and properties. Able to understand the size and structure relationship and their suitability for an given engineering application.

MICRO ELECTRO MECHANICAL SYSTEMS (MEMS) AND NANOELECTROMECHANICAL SYSTEMS (NEMS)

Sub Code	**:**	**14INT23**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objectives

1. Learn about basics and typical applications of microsystems
2. Illustrate scaling laws & microsensors and microactuators
3. Illustrate the various principles of operations of mems transducers
4. Learn basic electrostatics and its applications in MEMS sensors and actuators
5. Learn about ways to fabricate& a packaging needs MEMS device

Course Content

1. Introduction To MEMS : Historical background of Micro Electro Mechanical Systems, Feynman' s vision, Nano Technology and its Applications Multi-disciplinary aspects, Basic Technologies, Applications areas, Scaling Laws in miniaturization, scaling in geometry, electrostatics, electromagnetic, electricity and heat transfer.

10 Hours

2. Micro And Smart Devices And Systems: Principles : Transduction Principles in MEMS Sensors: Micro sensors-thermal radiation, mechanical and bio-sensors, Actuators: Different actuation mechanisms - silicon capacitive accelerometer, piezo-resistive pressure sensor, blood analyzer, conductometric gas sensor ,silicon micro-mirror arrays, piezo-electric based inkjet print head, electrostatic comb-driver , Smart phone application, Smart buildings

10 Hours

3. Materials & Micro manufacturing: Semiconducting Materials., Silicon, Silicon dioxide, Silicon Nitride , Quartz, Poly Silicon, Polymers, Materials for wafer processing, Packaging Materials Silicon wafer processing, lithography, thin-film deposition, etching (wet and dry), wafer-bonding. Silicon micromachining: surface, bulk, LIGA process, Wafer bonding process.

10 Hours

4. Electrical and Electronics Aspects : Electrostatics, Coupled Electro mechanics, stability and Pull-in phenomenon, Practical signal conditioning Circuits for Microsystems. Characterization of pressure sensors, RF MEMS. Switches varactors , tuned filters. Micromirror array for control and switching in optical communication, Application circuits based on microcontrollers for pressure sensor, Accelerometer, Modeling using CAD Tools (Intellisuite)

10 Hours

5. Integration And Packaging Of Microelectromechanical Systems: Integration of microelectronics and micro devices at wafer and chip levels. Microelectronic packaging: wire and ball bonding, flip-chip. Microsystem packaging examples, Testing of Micro sensors, Qualification of Mems devices

10 Hours Text Book:

1. G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, V. K. Aatre, "Micro and Smart Systems", Wiley India, 2010.

2. T R Hsu, "MEMS and Microsystems Design and Manufacturing", Tata McGraw Hill, 2nd Edition, 2008

Reference Books

3. Chang Liu, "Foundations of MEMS", Pearson International Edition, 2006.
4. S. D. Senturia, "Micro System Design", Springer International Edition, 2001.

Course outcome

Students will be able to

1 Understand the basics and develop applications for microsystems
2 operations of mems transducers
3 Applications of electrostatics in MEMS sensors and actuators
4 Fabricate MEMS device

NANOMATERIALS AND ENERGY SYSTEMS

Sub Code	**:**	**14INT24**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objective:

Learn about basic principles of different renewable energy technology. Apply nanomaterial in improving renewable energy storage and generation application. Understand the nanosize and morphology influence on improving energy generation and storage efficiency.

Course Content

1. Renewable energy Technology: Energy challenges, nanomaterials and nanostructures in energy harvesting, developments and implementation of nanotechnology based renewable energy technologies, solar cell structures: quantum well and quantum dot solar cells, photo-thermal cells for solar energy harvesting, thin film solar cells, CIGS solar cells, Dye sensitized solar cells. Organic PV cells, Concentrated solar power (CSP): Reflective materials, absorptive coatings, thermal storage.

10 Hours

2. Energy storage: Introduction, Battery types, Li-ion Battery, Battery components materials, cathodes, anodes, effect of nanosize on energy storage and electrode materials performance. LIB for automobiles application, EV's, HEV, PHEV and power grid.

10 Hours

3. Super capacitors: Introduction, Electrochemical energy storage, Electrochemical capacitors, Electrochemical double layer capacitor, electrode materials supercapacitors, Hybrid Nanostructures for supercapacitors- metal oxides, conducting polymers, Electrolytes for super capacitors, types of electrolytes.

10 Hours

4. Hydrogen storage technology: Hydrogen production methods, purification, hydrogen storage methods and materials: metal hydrides and metal organic framework materials, volumetric and gravimetric storage capacities, hydriding and dehydriding kinetics, high enthalphy formations and thermal management during hydriding reaction, multiple catalytic- degradation of sorption properties, automotive applications. Catalyst of hydrogen production, steam reforming & Water splitting. Nanoporous membranes for hydrogen separation.

10 Hours

5. Fuel cell technology: Fuel cell principles, types of fuel cells (Alkaline Electrolytie, phosphoric acid, Molten carbonate, solid oxide and direct methanol and proton exchange fuel cells), Principle and operation of proton exchange membrane (PEM) fuel cell, materials and fabrication methods for fuel cell technology, micro fuel cell power sources-biofuels.

10 Hours

Text Book

1. D. Linden, Handbook of Batteries and Fuel Cells, Mcgraw-Hill, Noew York,1984
2. W. A. van Schalkwijk and B. Scrosati, Advances in Lithium- Ion Batteries, Kluwer Academic Publishers, Newyork, 2002
3. Linden , D. and Reddy , T.B. (2002) Handbook of Batteries , 3rd edn , McGraw - Hill , New York.

Reference

1. Crompton, T.R. (2000) Battery Reference Book , 3rd edn , Newnes , Oxford .
2. K. E. Aifantis and S. A. Hackney and R. Vasant Kumar, High Energy Density Lithium Batteries, Wiley-VCH Verlag, 2009.
3. University of Cambridge (2005) DoITPoMS Teaching and Learning Packages,http://www.doitpoms.ac.uk/tlplib/batteries/index.php (accessed 5 February 2010).

Course Outcome:

Students get a clear understanding of nanotechnology being

employed for different energy and environment applications.

Elective – II

ADVANCED MATERIALS

Sub Code	**:**	**14INT251**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objective

Provide foundation about crystal structure, arrangement of atoms in different structure. Course gives an over view of various advance materials and their application. Enrich students with advanced material science techniques.

Course Content

1. Crystal structure: Crystal systems, Crystal classes, Bravais lattice. Unit cell: Wigner-Seitz cell, equivalent positions in a unit cell. Notations of planes and directions. Atomic packing: packing fraction, Co-ordination number. Examples of simple crystal structures: NaCl, ZnS and diamond. Symmetry operations, point groups and space groups.

X-ray diffraction: X-ray diffraction, Bragg law. Laue equations. Atomic form factor and Structure factor. Concept of reciprocal lattice and Ewald's construction. Experimental diffraction methods: Laue, Rotating crystal method and Powder method.

10 Hours

2. Crystal binding: Types of binding. Van der Waals-London interaction, Repulsive interaction. Modelung constant. Born's theory for lattice energy in ionic crystals and comparison with experimental results. Ideas of metallic binding, Hydrogen bonded crystals.

Lattice vibrations: Vibrations of monoatomic lattices. First Brillouin zone. Quantization of lattice vibrations - Concept of Phonon, Phonon momentum. Specific heat of lattice (qualitative).

10 Hours

3 **Photonic Materials:** Need For New Photonic Materials, composite materials for nonlinear optics, nanostructured waveguides for nonlinear optics quantum and nonlinear optics for advanced imaging applications.

Spintronics Materials: Modeling the growth of Mn on semiconductor substrates, Dilute magnetic semiconductor nanocrystals, Advances in wide bandgap materials for semiconductor spintronics

10 Hours

4. **Smart Materials and Systems:** Thermoresponsive materials, piezoelectric materials, electrostrictive and magnetostrictive materials, Magnetic materials, superparamagntism in metallic nanoparticles, Giant and colossal magnetic materials, ferrofluids, ER and MR fluids, biomimetic materials, smart gel, shape memory alloys and polymers.

10 Hours

5. **Nanocomposites:** Polymer nanocomposites, Nanofiber or Nanotube Fillers, Nanotube/Polymer Composites, Layered Filler Polymer Composite Processing, Polypropylene and Polyethylene Matrices, Polymethylmethacrylate/Polystyrene Matrices, Epoxy and Polyurethane Matrices. Carbon Based Nanocomposites, Functional Low-Dimensional Nanocomposites, Encapsulated Composite Nanosystems, Magnetic Multilayer Nanocomposites.

10 Hours

Text Books

1. Introduction to Solid State Physics, C. Kittel, Wiley Eastern
2. A practical approach to X-Ray diffraction analysis by C.Suryanarayana
3. Semiconductor Physics, P. S. Kireev, MIR Publishers.

References

1. Solid State Physics, A. J. Dekkar, Prentice Hall Inc.
2. Introduction to Superconductivity, M. Tinkham, McGraw-Hill, International Editions
3. Elementary Solid State Physics: Principles and applications, M. A. Omar, Addison-Wesley.

Course Outcome:

Students will able to

1. Understand the crystal structure and characterization of various nanomaterials
2. Evaluate the characteristic crystal structure and their influence on properties of the materials.
3. Demonstrate their knowledge in advanced material science which helps in applications of various materials in engineering applications.

BIOSENSORS AND INSTRUMENTATION

Sub Code	**:**	**12INT252**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objective:

Presents underlying basic concept and principles of various sensors used to develop nanosensors. Background to understand the sensor characteristic and their physical effect. Knowledge about sensors to detect small molecules, DNA, proteins, and cells in the context of their applications.

1. Fundamentals of sensors: Micro and nano-sensors, biosensor, packaging and characterization of sensors, method of packaging at zero level, and first level. Thermal energy sensors: temperature sensors, heat sensors, electromagnetic sensors, electrical resistance sensors, electrical current sensors, electrical voltage sensors, electrical power sensors, magnetic sensors, Mechanical sensors, pressure sensors, gas and liquid flow sensors, position sensors, chemical sensors, optical and radiation sensors- gas sensor.

8 Hours

2. Sensor Characteristics and Physical Effects: Active and Passive sensors – Static characteristic: Accuracy, offset and linearity – Dynamic characteristic: First and second order sensors, Physical effects involved in Signal Transduction: Photoelectric effect – Photodielectric effect, Photoluminescence Effect – electroluminescence effect – chemiluminescence effect, Doppler effect, Barkhausen effect, Hal effect – nernst / Ettinshausen effect, Thermoelectric effect – Peizoresistive effect – piezoelectric effect, pyroelectric effect, magneto-mechanical effect (magnetostriction) – Magnetoresistive effect, Faraday-Henry Law, magneto optice Kerr effect, Kerrand Pockels Effect.

Sensors for measurement of chemicals: potentiometric sensors, ion selective electrodes, ISFETS; Amperometric sensors, Clark Electrode.

14 Hours

3. Sensor Architecture and Classification:

Medically Significant Measurands, Functional Specifications of Medical Sensors; Sensor characteristics : linearity, repeatability, hysteresis and drift. Sensors for physical measurands: strain, force, pressure, acceleration, flow, volume, temperature and biopotentials.

8 Hours

4. Biological Sensors: Sensors/receptors in the human body, basic organization of nervous system, neural mechanism. Chemoreceptor: hot and cold receptors, barro receptors, sensors for smell, sound, vision, osmolality and taste. Noninvasive blood-gas monitoring, Blood-glucose sensors. Noninvasive Biosensors in Clinical Analysis. Applications of Biosensor-based instruments for the bioprocess industry. Application of Biosensors for environmental samples.

12 Hours

5. Nano based Inorganic Sensors

Introduction to Density of states (DOS), one dimensional gas sensors:- gas sensing with nanostructured thin films, absorption on surfaces, metal oxide modifications by additives, surface modifications, Nano optical sensors, nano mechanical sensors, plasmon resonance sensors with nano particles.

08 Hours

Text Books

1. Nanotechnology enabled sensors by Kouroush Kalantar – Zadeh, Benjamin Fry, Springer Verlag New York, (2007)
2. Biosensing: International Research and Development, Jerome Schultz, Milar Mrksich, Sangeeta N. Bhatia, David J. Brady, Antionio J. Ricco, David R. Walt, Charles L. Wilkins, Springer 2006
3. Sensors and signal conditioning, 2nd edition Ramon Pallas-Areny, John G. Webster John Wiley & Sons (2001).

References:

1 Handbook of Biosensors and Electronic Noses: Medicine, Food and the Environment: CRC-Press; 1 edition;1996.
2 D. L. Wise, Biosensors: Theory and Applications, CRC Press,1993.

Course Outcome:

Students will able to

1. Learn sensors architecture and classification,
2. Develop the biological sensors and inorganic nanosensors.
3. Demonstrate the knowledge of sensor characteristic and their physical effect.
4. Design the simple sensor device to detect small biomolecules, gas molecules and so on.

MICRO AND NANO FLUIDICS

Sub Code	**:**	**12INT253**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objective:

A comprehensive understanding of micro and nano fluidics. Learn about Fabrication techniques of Nanofluidic channels, Lab-on-chip concept and application. Understanding the behavior of Biomolecule's in microfluidic channels.

Course content

1. Introduction: Fundamentals of kinetic theory-molecular models, micro and macroscopic properties, binary collisions, distribution functions, Boltzmann equation and Maxwellian distribution functions-Wall slip effects and accommodation coefficients, flow and heat transfer analysis of microscale Couette flows, Pressure driven gas micro-flows with wall slip effects, heat transfer in micro-Poiseuille flows, effects of compressibility.

Pressure driven liquid microflow: apparent slip effects, physics of near-wall microscale liquid flows, capillary flows, electro-kinetically driven liquid micro - flows and electric double layer (EDL) effects, concepts of electroosmosis, electrophoresis and dielectro-phoresis.

12 Hours

2. Laminar flow: Hagen-Poiseullie eqn, basic fluid ideas, Special considerations of flow in small channels, mixing, microvalves & micropumps, Approaches toward combining living cells, microfluidics and 'the body' on a chip, Chemotaxis, cell motility. Case Studies in Microfluidic Devices.

Ionic transport: Polymer transport – microtubule transport in nanotuble channels driven by Electric Fields and by Kinesin Biomolecular Motors - Electrophoresis of individual nanotubules in microfluidic channels.

12 Hours

3. Fabrication techniques for Nanofluidic channels – Biomolecules separation using Nanochannels - Biomolecules Concentration using Nanochannels – Confinement of Biomolecules using Nanochannels.

Hydrodynamics: Particle moving in flow fields – Potential Functions in Low Renoylds Number Flow – Arrays of Obstacles and how particles Move in them: Puzzles and Paradoxes in Low Re Flow.

08 Hours

4. Microfluidics and Lab-on-a-chip: Microfluidic Devices - Microchannels, Microfilters, Microvalves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Concepts and Advantages of Microfluidic Devices - Fluidic Transport - Stacking and Scaling – Materials for The Manufacture (Silicon, Glass, Polymers) - Fluidic Structures - Fabrication Methods - Surface Modifications - Spotting - Detection Mechanisms. Microcontact printing of Proteins-Strategies- printing types- methods and characterization- Cell nanostructure interactions-networks for neuronal cells. Applications in Automatic DNA sequencing, DNA and Protein microarrays.

09 Hours

5. BioMEMS: Introduction and Overview, Biosignal Transduction Mechanisms: Electromagnetic Transducers Mechanical Transducers, Chemical Transducers, Optical Transducers – Sensing and Actuating mechanisms (for all types). Case Studies in Biomagnetic Sensors, Applications of optical and chemical transducers. Ultimate Limits of Fabrication and Measurement, Recent Developments in BioMEMS and BioNEMS - An alternative approach to traditional surgery, Specific targeting of tumors and other organs for drug delivery, Micro-visualization and manipulation, Implantation of microsensors, microactuators and other components of a larger implanted device or external system (synthetic organs).

09 Hours

Text Books

1. Joshua Edel "Nanofluidics" RCS publishing, 2009.
2. Patric Tabeling "Introduction to Microfluids" Oxford U. Press, New York 2005.
3. K. Sarit "Nano Fluids; Science and Technology", RCS Publishing, 2007.

References

1. M. Madou, Fundamentals of Microfabrication, CRC Press, 1997
2. G. Kovacs, Micromachined Transducers, McGraw-Hill, 1998

Steven S Saliterman, Fundamentals of BioMEMS and Medical Microdevices, 2006

Course Outcome:

Students will able to

1. Demonstrate knowledge about Pressure driven liquid microflow, laminar flow, ionic transport, fabrication techniques for nano fluidic channels.
2. Analyze the biomolecule behavior in microfluidic channels.
3. Design the lab on chip devices and BiMEMS devices and their applications.

LAB COMPONENT II

Sub Code	**:**	**14INT26**	**IA Marks**	**:**	**25**
Hrs/ Week	**:**	**03**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**36**	**Exam Marks**	**:**	**50**

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1 Synthesis of Carbon nanotubes/Graphene sheets by Chemical Vapor Deposition (CVD) method

2 Sterilization technique
3 Green synthesis of nanoparticle using plant/flower/fungal extract.
4 Antibiological activity of nanomaterials
5 Primary Cell and Microbial cell culture
6 Spectroscopic techniques: UV-visible, IR spectroscopy and principle, Sample measurement, analysis of data, interpretation
7 Measurement and analysis of Carbon and metal oxide nanomaterials by Raman spectroscopy.
8 Measurement and analysis of X-ray diffraction, crystal structure identification and data interpretation, crystal size determination
9 AFM operation and observation of nanostructures
10 Current (I) and Voltage (V) measurements
11 Gas/pressure monitoring Sensors device fabrication and measurement
12 Dye sensitized solar cell device fabrication and I-V measurement

NANOTECHNOLOGY AND ENVIRONMENT

Sub Code	:	**14INT41**	**IA Marks**	:	**50**
Hrs/ Week	:	**04**	**Exam Hours**	:	**03**
Total Hrs.	:	**50**	**Exam Marks**	:	**100**

Course Objective:

Students to learn applications of different nanomaterials for

Environmental remedies, removal of pollutant from exhaust gases. Understand the effect of nanoparticle on health and environment and their toxicology.

Course Content

1. Environmental Application of Nanomaterials: Metal oxide nanoparticles organic contamination remediation, Nanoactive materials, Adsorption of hazardous chemicals by metal oxide nanoparticles, Adsorption of chemical warfare agents by metal oxide nanoparticles.

08 Hours

2. **Nanostructure catalytic materials**: Nanostructured metals like Pt, Pd and Fe, nanostructured ceramics like silica, silcate and alumina, pillared clays, colloids and porous materials.

Meosoporous and Nanoporous materials: Introduction, synthesis and characterization, properties and application with suitable examples, unipore size, bimodal pore size, Nanoporous materials, synthesis and application.

08 Hours

3 Nanomaterials as Adsorbents: Introduction, Adsorption at the Oxide Nanoparticles/Solution Interface, Nanomaterial-Based Removal of nanoparticles-Principle of particle removal - Removal of nanoparticles suspended in gas - Removal of nanoparticles in liquid. Adsorbents for CO_2, H_2S, Pb, NO_x,etc. Catalyst for exhaust gas treatment.

Adsorbents for Water and Wastewater Treatment, Nanomaterials for Groundwater Remediation- Reactivity, Fate, and Lifetime Delivery and Transport Issues

08 Hours

3. Environmental and Safety issues: Nanoparticles and environment - Nanoparticles in atmospheric environment, Ground water environments and in exhaust gases - Nanoparticles in wastewater - Indoor environments Industrial processes and nanoparticles; Safety of nanoparticles- Problems caused by nanoparticles - Health effects on nanoparticles - Safety assessment for the nanoparticles.

08 Hours

5. **Nanotoxicology:** Introduction, Laying a firm Foundation for Sustainable Nanotechnologies. Inhalation of nanomaterials–overview, Nanoparticle exposure and systematic cardiovascular effects. Respiratory particulate matter exposure and cardiovascular toxicity, Toxicity of different nanomaterials Toxicological assessment of nanoparticles: Toxicity of polymeric nanoparticles. Ecotoxicological Impacts of Nanomaterials, Effects of Nanomaterials on Microorganisms, Assessment of Ecotoxicity, Nanomaterial Interaction with Microbial Cell Components.

12 Hours

Text Books

1. Glen E. Fryxell, Guozhong Cao, Environmental Applications of Nanomaterials: Synthesis, Sorbents and Sensors
2. Mark R. Wiesner, Jean-Yves Bottero, Environmental Nanotechnology: Applications and Impacts of Nanomaterials
3. J. B Park, "Biomaterials Science and Engineering", Plenum Press, New York, 1984.
4. P.P. Simeonova, N. Opopol and M.I. Lus ter, "Nanotechnology - Toxicological Issues and Environmental Safety", Springer 2006.

References

1. J.J. Davis, Dekker, "Encyclopedia of Nanoscience and nanotechnology"
2. Dracy J. Gentleman, Nano and Environment: Boon or Bane? Environmental Science and technology, 43 (5), P1239, 2009
3. Vinod Labhasetwar and Diandra L. Leslie, "Biomedical Applications of nanotechnology", A John Willy & Son Inc, N.J, USA, 2007.

Course Outcome:

Students will be able to

1. Apply nanomaterials in different environmental applications.
2. Demonstrate knowledge about the nanoparticles effect on health and safety issues.
3. Nanoparticles toxicity and their effect on health.

Elective – III

NANOTECHNOLOGY AND DRUG DELIVERY SYSTEMS

Sub Code	**:**	**14INT421**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objective:

Students will learn underlying principles of drug delivery systems. Understand the application of nanostructures as drug delivery systems. Nanoparticles based drug formulation for cancer therapy and bio imaging application.

Course Content

1. Principles of drug delivery systems (DDS): Design of drug delivery systems, Aims of DDS, Modes of drug delivery, ADME hypothesis – controlled drug delivery, site specific drugs , barriers for drug targeting, passive and active targeting, Strategies for site specific, time and rate controlled delivery of drugs, antibody based and metabolism-based targeting.

8 Hours

2. Nano sized Drug Carriers: Structure and Preparation- Liposomes, Cubosomes and Hexosomes, Solid Lipid Nanoparticles (SLP). Lipid based colloidal system, Liposomal Drug Carriers, Dendrimer (PAMAM), Polymer Micelle, Ceramic and Magnetic nanoparticle, Polymer drug conjugates. Nanotubes, Nanowires, Nanocage, Nanorods, Nanofibers, and Fullerenes, Carbon nanotubes biocompatibility. Smart drug delivery systems, Multifunctional Drug carriers, organic and inorganic composites. Problems with DDS, Drug loading efficiency in nanovehicles, complexity of Nanocarriers, interface between synthetic materials and biological tissues or components, safety and ethical issues, Nanotechnology for future DDS.

10 Hours

3. Drug Discovery & Cancer therapy: Drug Discovery Using Nanocrystals, Drug Discovery Using Resonance Light Scattering (RLS) Technology. Nanosensors in Drug Discovery, Drug Delivery Applications, Nanorobots, Benefits of Nano-Drug Delivery. Use of microneedles and nanoparticles for local highly controlled drug delivery. Metal nanoparticles in drugs discovery. Nanotechnology for Cancer therapy-Nanobodies, Nanoparticles, nanoshells, Nanobombs, pebbles for brain tumor therapy, Targeting through angiogenesis and Folate receptors Liposomal formulation in cancer therapy, application of liposomes in pharmaceutical and cosmetic applications.

12 Hours

4. Nanomedicines: Introduction, Applications of nanobiotechnology in medicine, Role of nanotechnology in methods of treatment, Nanomedicines for Nervous system, Developing Nanomedicines, Protocols for nanodrug Administration, Nanotechnology in Diagnostics applications, materials used in Diagnostics and Therapeutic applications - Molecular Nanomechanics, Molecular devices, Nanomedicines for Skin disorders, wound healing, eye diseases, infections, Nanotubes for detection and destruction of bacteria. **10 Hours**

5. Nanoanalytics: Nanoparticles for biological labelling, Nano-Imaging Agents, Nanoparticles molecular labels, Immunogold-silver staining, combined fluorescent and gold probes, Protein Labeling, gold cluster labelled peptides, gold cluster conjugates of other small molecules, gold-lipids metallosomes, Larger covalent particles labels, gold targeted to His Tabs, gold cluster nanoscrystals.

10 Hours

Text Books

1. Nanotechnology in Drug Delivery: Melgardt M. de Villiers, Pornanong Aramwit, glen s. Kwon, Springer, 2009
2. NanoBiotechnology: BionInspired Devices and Materials for the Future: Oded Showeyov, Ilan Levy, Humana Press, New Jersey 2010
3. Nanobiotechnology, Concepts applications and Perspectives: C. M. Niemeyer and Chad A. Mirkin, Wiley VCH, 2009

Reference

1. Bionanotechnology Global prospects II: david E Reisner, CRC Press 2012
2. Nanoparticulate Drug Delivery Systems Deepak Thassu, Michel Deleers (Editor), Yashwant Pathak
3. Drug Delivery and Targetting, A.M.Hillery, CRC Press, 2002.
4. Bio-Applications of Nanoparticles Warren C.W. Chan
5. Lisa Brannon-Peppas, James O. Blanchette Nanoparticle and targeted systems for cancer therapy Advanced Drug Delivery Reviews 56 (2004) 1649– 1659

Course Outcome:

Students will be able to

1. Demonstrate the knowledge to develop nanoparticle based new types of biomedical markers and therapeutic agents.
2. Evaluate the suitable nanostructure for drug delivery systems application.
3. Develop nanoparticles based drug formulation for cancer therap.

NANOPHTONICS

Sub Code	**:**	**14INT422**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objective:

The course gives an introduction to basic concepts of nanophotonics. It also provides overview of various semiconductor nanomaterials and their characteristics features along with its applications.

Course Content

Introduction to Nanophotonics: Nano photonics at a Glance, Multidisciplinary approach, Photons and Electrons: Similarities and Differences, Propagation, Nanoscale Optical Interaction, Free-Space Propagation, Confinement of Photons and Electrons, Nanoscale Confinement of Electronic Interactions.

10 Hours

Quantum-Confined Materials and characterization

Inorganic Semiconductors, Quantum Wells, Wires Dots, Rings, Manifestations of Quantum Confinement Dielectric Confinement Effect, Super lattices, Core-Shell Quantum Dots and Quantum Dot-Quantum Wells Quantum-Confined Structures as Lasing Media, Organic Quantum-Confined Structures, Characterization of Nanomaterials, Different techniques- X Ray, Electron Microscopy. **11 Hours**

3. Photonic Crystals

Basics Concepts, Theoretical Modeling of Photonic Crystals, Features of Photonic Crystals, Methods of Fabrication , Photonic Crystal Optical Circuitry, nonlinear Photonic Crystals, Photonic Crystal Fibers (PCF), Photonic Crystals and Optical Communications, Photonic Crystal Sensors.

10 Hours

4. Nanolithography

Two-Photon Lithography, Near-Field Lithography, Near-Field Phase-Mask Soft Lithography, Plasmon Printing, Nanosphere Lithography, Dip-Pen Nanolithography, Nanoimprint Lithography, Photonically Aligned Nanoarrays.

9 Hours

5. **Silicon Photonic Applications**

Communications and Interconnects, Radio-over-fiber (RoF) RF Applications, Nonlinear Optical Effects in Silicon and Applications, Silicon Amplifiers and Lasers, Wavelength Conversion, Sensing - Physical Sensors, Chemical Sensors, Biochemical Sensors, Integrated Lab-on-a-chip, Power Generation and Conversion, Information Technology, Sensor Technology, Nanomedicine.

10 Hours

Text Books

1. Paras N Prasad, Nanophotonics, Wiley Interscience, 2004

2. Graham T Reed, Silicon Photonics, John Wiely and Sons, 2008

3. David G. Bucknall. Nanolithography and patterning techniques in microelectronics, CRC Press,

Course Outcome:

Students will be able to

1. Understand the basic principles involved photonics and electronics applications
2. Demonstrate knowledge about photonic, semiconductor nanostructures in developing their application**s**
3. Knowledge to apply nanolithography for nanphotonics based devices.

EMERGING COMPUTING TECHNIQUES

Sub Code	**:**	**14INT423**	**IA Marks**	**:**	**50**
Hrs/ Week	**:**	**04**	**Exam Hours**	**:**	**03**
Total Hrs.	**:**	**50**	**Exam Marks**	**:**	**100**

Course Objective:

The course gives introduction on different types of memories and computing techniques.

Course Content

1. Advanced semiconductor memories: Introduction, Overview of semiconductor memories, advanced semiconductor memory developments, future memory directions.

Single electron memories: Single electron device theory, single electron memory characteristics and configurations, single electron devices fabrication techniques, nanocrystal memory devices. Phase change nonvolatile memories. Protonic nonvolatile memories. Nanotech memories, solid state holographic memories.

10 Hours

2. Ferroelectric RAMs: Background of ferroelectric memory technologies, basic ferroelectric technology, ferroelectric effect, properties of ferroelectric capacitor.

Ferroelectric RAMs with 2T2C cells: Overview of 2T2C ferroelectric RAM cell technology, operation of a 2T2c ferroelectric RAM cell, characteristics of a 2T2C ferroelectric memory.

Magnetic RAMs: Overview of magnetic memories, Overview and development of Anisotropic magnetic RAM. Giant-Magneto-Resistive (GMR) effect.

Spin Valve Cell and operation: Overview, development and characteristics of spin valve MRAM. Overview and development of pseudo spin valve MRAM cell. Magnetic tunnel junction technology. Magnetic tunneling junction memory cells.

10 Hours

3. Silicon nanocrystals/nanodots: Overview and theory of silicon nancrystal/nanodots devices. Silicon nanocrystal device using a PMOS transistor. Comparison of implantation vs deposition of silicon nanocrystals.

Alternative Nanocrystal devices: Double stacked nanodots, Tin (Sn) nanocrystals, model of a Sn nanocrystal memory, Germanium nanocrystals, Silicon nanocrystals with oxide-nitride dielectrics. Manufacturing techniques for nanocrystals. Applications for silicon nanocrystal memories.

10 Hours

4. Logic devices: Fundamentals, Requirement for logic devices, dynamic properties of logic gates, threshold gates. Physical limits to computation.

Concepts of logic devices: Classifications, two-terminal devices, field effect devices, coulomb blockade devices, spintronics, quantum cellular automata, quantum computing, DNA computer.

10 Hours

5. Architectures: Flexibility of systems for information processing, parallel processing and granualirity, Teramac – a case study. Performance of information processing systems: Basic binary operations, measures of performance, processing capability of biological neurons, performance estimation for human brain. Ultimate computation: Power dissipation limit, dissipation in reversible computation, the ultimate computer.

10 Hours

Text Books

1. Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Devices. Rainer Waser (Ed). Wiley-VCH.
2. Advanced Semiconductor Memories: Architectures, Designs and Application. Ashok K Sharma. Wiley.
3. Emerging Memories: Technologies and Trends. Betty Prince. Kluwer Academic Publishers.

Course Outcome:

Students will able to

1. Apply computing techniques simulating nanoelectronics devices
2. Demonstrate knowledge about different memory devices and their application
3. Design semiconductor nanocrystal memories device.