

# **COIMBATORE INSTITUTE OF TECHNOLOGY**

(Government Aided Autonomous Institution Affiliated to Anna University, Chennai)

**COIMBATORE - 641 014, TAMILNADU, INDIA**

**DIAMOND JUBILEE**

(1956 - 2016)



**DEPARTMENT OF CHEMICAL ENGINEERING**  
**M.Tech NANO SCIENCE AND TECHNOLOGY**

**Curriculum and Syllabi**

**Under Choice Based Credit System**

( For the students admitted during 2019 - 2020 and onwards )

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# **COIMBATORE INSTITUTE OF TECHNOLOGY**

(Government Aided Autonomous Institution Affiliated to Anna University, Chennai)

## **VISION AND MISSION OF THE INSTITUTE**

### **VISION**

The Institute strives to inculcate a sound knowledge in Engineering along with realized social responsibilities to enable its students to combat the current and impending challenges faced by our country and to extend their expertise to the global arena.

### **MISSION**

The Mission of the institute is to impart high quality education and training to its students to make them world-class Engineers with a foresight to the changes and problems and pioneers to offer innovative solutions to benefit the nation and the world at large.

**DEPARTMENT OF CHEMICAL ENGINEERING  
COIMBATORE INSTITUTE OF TECHNOLOGY**

**VISION AND MISSION OF CHEMICAL ENGINEERING**

**VISION**

The Department of Chemical Engineering strives for excellence in all aspects of teaching and research, to produce Chemical Engineers of quality required in Industries/ academic/ research organizations and serves the society at national and international standards.

**MISSION**

The Department is committed to continue building on its tradition of excellence and innovation by preparing the engineers of tomorrow and by meeting the challenges of a changing world through education, research, and service to its profession and the community.

**DEPARTMENT OF CHEMICAL ENGINEERING  
COIMBATORE INSTITUTE OF TECHNOLOGY**

**PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)**

- I. Experienced and technically competent engineers in the field of Nano Science and Technology with a solid foundation in science and technology which will enable them to apply a range of different approaches to problem analysis and synthesis as well as different solution strategies in tackling complex technical problems in the industry.
- II. Have a sound knowledge base and skill sets to develop and expand professional careers in fields related to chemical synthesis, processes, modeling and simulation, computer-based design of industrial processes.
- III. Technology pioneers and change agents as they apply their conceptual knowledge and engineering skills not only to design, develop and deploy state of the art nano science and technology related tools, techniques and technologies but also to catalyze change in the workplace and in the economy at large.
- IV. Lifelong learners who in a formal sense will go on to enroll in, and successfully graduate from, more advanced graduate and professional education and certification programs that are nationally and/or internationally recognized in technology, science or business, and who, more informally, are and will remain wise enough to diagnose, analyze and remedy the gaps or deficits in their own knowledge bases over time by gleaning what they can from the environment on their own.

**DEPARTMENT OF CHEMICAL ENGINEERING  
COIMBATORE INSTITUTE OF TECHNOLOGY**

**PROGRAMME OUTCOMES (POs)**

- a) The graduates have an ability to apply knowledge of advanced mathematics, science and engineering principles to practical problems in their respective professions.
- b) The graduates have an ability to improve the efficiency of processes and quality of products in chemical and allied industry.
- c) The graduates have an ability to identify, formulate and solve problems.
- d) The graduates have an ability to design innovative processes and equipment suitable to the contemporary needs of the chemical industry and to promote the qualities of leadership and employability.
- e) The graduates have an ability to work in multidisciplinary teams consisting of professionals from various disciplines of science and technology.
- f) The graduates have an ability to be employed in software based jobs related to nano science and technology.
- g) The graduates have an ability to communicate effectively in multicultural environment and work with professional ethics and responsibility.
- h) The graduates have an ability to gather information and procreate effective technical reports and oral presentations.
- i) The graduates have an ability to design systems, components or processes to meet specified objectives within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability in the field of nano science and technology.
- j) The graduates have an ability to engage in lifelong research and to update technical know-how by self-learning besides learning a great deal by associating with professional bodies and alumni.
- k) The graduates have an ability to succeed in the graduate competitive examinations and pursue research in nano science and technology or lateral disciplines.

# COIMBATORE INSTITUTE OF TECHNOLOGY

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## M.Tech NANO SCIENCE AND TECHNOLOGY

### SUBJECTS OF STUDY

#### Semester I

Course Code	Course Name	Contact Hours	L	T	P	C	Category
19MN11	Modeling and Simulation of Particulate Processes	4	3	1	0	4	FC
19MN12	Quantum Mechanics	3	3	0	0	3	FC
19MN13	Materials Science	3	3	0	0	3	PC
19MN14	Physical and Chemical Synthesis of Nanomaterials	3	3	0	0	3	PC
	Elective - I	3	3	0	0	3	PE
19MN15	Material Synthesis and Characterization Laboratory-I	4	0	0	4	2	PC
19MN16	Modelling and Simulation Laboratory	4	0	0	4	2	PC
19MN17	Seminar and Technical Writing	3	0	0	3	1	EEC
	<b>TOTAL</b>					<b>21</b>	

#### Semester II

Course Code	Course Name	Contact Hours	L	T	P	C	Category
19MN21	Physical and Chemical Methods for Characterization of Nanomaterials	3	3	0	0	3	PC
19MN22	Processing and Properties of Nanostructured Materials	3	3	0	0	3	PC
19MN23	Thermodynamics and Kinetics	4	3	1	0	4	PC
	Elective - II	3	3	0	0	3	PE
	Elective - III	3	3	0	0	3	PE
	Elective - IV	3	3	0	0	3	PE
19MN24	Material Synthesis and Characterization Laboratory-II	4	0	0	4	2	PC
19MN25	Mini Project	4	0	0	4	2	EEC
	<b>Total</b>					<b>23</b>	

**Semester III**

Course Code	Course Name	Contact Hours	L	T	P	C	Category
	Elective - II	3	3	0	0	3	PE
	Elective - III	3	3	0	0	3	PE
	Elective - IV	3	3	0	0	3	OE
	<b>Total</b>					<b>9</b>	

**Semester IV**

Course Code	Course Name	Contact Hours	L	T	P	C	Category
19MN41	Project Work and Viva-Voce					18	EEC
	<b>Total</b>					<b>18</b>	

**Total Credits : 71****LIST OF PROFESSIONAL ELECTIVES**

Course Code	Course Name	Contact Hours	L	T	P	C	Category
19MNE01	Numerical Methods and Computer Programming	3	3	0	0	3	PE
19MNE02	Nanoscale Integrated Computing	3	3	0	0	3	PE
19MNE03	Nanotechnology in Energy Conversion and Storage	3	3	0	0	3	PE
19MNE04	Semiconductor Nanoparticles	3	3	0	0	3	PE
19MNE05	Nano Devices and Sensors	3	3	0	0	3	PE
19MNE06	Polymers and Nanocomposites	3	3	0	0	3	PE
19MNE07	Thin Film Technology	3	3	0	0	3	PE
19MNE08	New Separation Techniques	3	3	0	0	3	PE
19MNE09	Crystal Growth Techniques	3	3	0	0	3	PE
19MNE10	Nanobiotechnology	3	3	0	0	3	PE
19MNE11	Biochemical Engineering	3	3	0	0	3	PE
19MNE12	Industrial Nanotechnology	3	3	0	0	3	PE
19MNE13	Nano pollution and E-waste Management	3	3	0	0	3	PE
19MNE14	Design and Analysis of Experiments	3	3	0	0	3	PE
19MNE15	Digital Process Dynamics and Control	3	3	0	0	3	PE
19MNE16	Research Methodology	3	3	0	0	3	PE
19MNE17	Intellectual Property Rights and Innovation	3	3	0	0	3	PE

## LIST OF OPEN ELECTIVES

Course Code	Course Name	Contact Hours	L	T	P	C	Category
19MNOE01	Nanoelectronics and Sensors	3	3	0	0	3	OE
19MNOE02	Safety Engineering	3	3	0	0	3	OE
19MNOE03	Societal Implications of Nanotechnology	3	3	0	0	3	OE

L : Lecture, T : Tutorial, P : Practical, C : Credit

- FC - Fundamental Course, PC - Professional Course, PE - Professional Elective, EEC - Employment Enhancement course
- Student can opt for a maximum of 1 open elective subject from other programmes during their entire programme of study

# 19MN11 - MODELING AND SIMULATION OF PARTICULATE PROCESSES

L	T	P	C
3	1	0	4

## ASSESSMENT : THEORY

### COURSE OUTCOMES

**CO1** : To recognize the importance of probabilities concepts and random variables in the particulate processing.

**CO2** : To practice the different concepts of Markov process in particulate processing.

**CO3** : To analyze the different components of population balance equation.

**CO4** : To develop the solution for the population balance equation.

**CO5** : To relate the concepts of population balance equation for different applications.

### PROBABILITY CONCEPTS

Events and set of events - Probabilities - Joint and Conditional Probabilities: Independence - Mean Values and Probabilities Density - Characteristic function - Cumulant Generating function - Gaussian and Poissonian Probability Distributions - Limits of sequences of Random variables. (12)

### MARKOV PROCESS

Stochastic Process - Markov Process - Continuity in Stochastic Processes - Differential Chapman-Kolmogorov Equation - Interpretation of Conditions and Results- Equations for Time development in Initial Time Backward Equations- Stationary and Homogeneous Markov Processes - Examples of Markov Process. (12)

### THE FRAMEWORK OF POPULATION BALANCE

Particle state vector-The Continuous phase vector - The number density function - The rate of change of Particle State Vector - The particles Space Continuum - The Reynolds Transport theorem - The population balance Equation - population balance Equation for open system - Equation for the Continuous Phase Vector - Random Changes in Particle State - Formulation of Population Balance Models - Similarity Behavior of Population Balance Equations. (12)

### THE SOLUTION OF POPULATION BALANCE EQUATIONS

Processes - Existence of Solution - The Method of Successive Approximations- The Method of Laplace Transforms - The Method of Moments and Weighted Residuals - The Method of Moments and Weighted Residuals - Similarity Behavior of Population Balance Equations. (12)

### APPLICATION OF POPULATION BALANCE EQUATIONS

Population balance equations - various particulate processes such as coagulation, aggregation, crystallization, condensation, breakage, attrition, growth - analytical solutions - numerical discretization methods - Applications. (12)

**TOTAL : 60**

### REFERENCES

1. D. T. Gillespie, *Markov Processes*, Academic Press: San Diego, 1992.
2. N. G. van Kampen, *Stochastic Processes in Physics and Chemistry*, 3rd Ed., Elsevier:Amsterdam, 2007.
3. H. C. Berg, *Random Walks in Biology*, Princeton University Press: New Jersey, 1983.
4. C. W. Gardiner, *Handbook of Stochastic Methods*, 2nd Ed., Springer: New York, 1997.
5. S. M. Ross, *Stochastic Processes*, 2nd Ed., Wiley-India: New Delhi, 2011.

6. *D. Ramkrishna, Population Balances: Theory and Applications to Particulate Systems in Engineering, Academic Press: San Diego, 2000.*
7. *A. D. Randolph and M. A. Larson, Theory of Particulate Processes: Analysis and Techniques of continuous Crystallization, Academic Press: San Diego, 1972.*
8. *S. K. Friedlander, Smoke, Dust and Haze: Fundamentals of Aerosol Dynamics, Oxford University Press, 2000.*

# 19MN12 - QUANTUM MECHANICS

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

**CO1** : To identify and understand the central concepts and principles in quantum mechanics.

**CO2** : To interpret the quantum physics behind the operation of devices.

**CO3** : To solve the Schrodinger's equation for simple one and two dimensional systems.

**CO4** : To understand the effects of wave symmetry and scattering phenomena.

**CO5** : To co-relate the analytical and numerical approach to quantum mechanical problems.

### THE SCHRODINGER'S EQUATION AND ITS MATHEMATICAL IMPLICATION

Development of Time Dependent Schrodinger's equation - Statistical interpretation of wave function - Normalization of wave function - Conservation of total probability, Dynamical variables and Hermitian operators - position, linear and angular momentum operators - Commutation relations - Ehrenfest theorem - Heisenberg uncertainty principle, Time Independent Schrodinger equation - Properties of energy eigen functions, Expansion postulate. (9)

### BOUND STATES & QUANTUM TUNNELING

Free particle - Momentum eigen functions, Energy levels of a particle - Infinite square well in one, two, and three dimensions - Density of states - Confined carriers - Electron wave propagation in devices - Quantum confinement - Penetration of a barrier - Tunnel effect - Basic principles of a few effective devices - Resonant tunnel diode, Superlattice, Quantum wire and Dot. (9)

### QUANTUM DYNAMICS

Time development of the wave function - Time evolution operator - Schrodinger, Heisenberg, and Interaction pictures of quantum dynamics - Time evolution - Free particle wave packet, One-dimensional harmonic oscillator, Two-state quantum systems. (9)

### IDENTICAL PARTICLES AND SCATTERING THEORY

System of Identical particles - Symmetrization of wave functions - Exchange interactions - Free electrons in a metal - Fermi gas - Mutual scattering of two particles - Separation of Schrodinger equation in laboratory and center of mass frames - Quantum theory of Scattering - Differential and total cross sections, Scattering amplitude - Derivation using Green's functions - Born approximation - Scattering by spherically symmetric potentials. (9)

### QUANTUM COMPUTATION

Quantum Bits - Single qubit gates - Multiple qubits - Controlled Not gate, Swap gate, Toffoli gate, Bell states - no-cloning theorem - Quantum Teleportation - Deutsch's Algorithm - Deutsch-Jozsa Algorithm - Quantum Fourier transform. (9)

**TOTAL : 45**

### REFERENCES

1. B.H. Bransden and C.J. Joachain, *Quantum Mechanics*, Pearson, Second Edition, 2007.
2. David J. Griffiths, *Introduction to Quantum Mechanics*, Pearson, Second Edition, 2009.
3. Richard L. Liboff, *Introductory Quantum Mechanics*, Pearson, Fourth Edition, 2003.
4. Mark Lundstrom, *Fundamentals of Carrier Transport*, Cambridge University Press, Second Edition, 2000.
5. Yoav Peleg, Reuven Pnini, ElyahuZaarur, and Eugene Hecht, *Schaum's Outline of Quantum Mechanics*, Tata McGraw Hill, Second Edition, 2010.
6. Eugen Merzbacher, *Quantum Mechanics*, John Wiley & Sons, Third Edition, 1999.
7. P.M. Mathews and K. Venkatesan, *Quantum Mechanics*, Tata McGraw Hill, Second Edition (2010).
8. AjoyGhatak and S. Lokanathan, *Quantum Mechanics*, Macmillan, Fifth Edition, 2009.

# 19MN13 - MATERIALS SCIENCE

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

**CO1** : To describe the physical properties of a material.

**CO2** : To understand the electronic properties of a semiconductor material.

**CO3** : To analyze the dielectric and optical properties of a material.

**CO4** : To explain the features and applications of smart materials.

### CRYSTAL STRUCTURE

Atomic structure- Atomic bonding in solids- Crystalline state of solids - Unit cells and Space lattices -Crystal structures - Crystal planes and directions - Miller Indices - Diffraction of X-rays by crystal - Bragg's equation - Correction to Bragg's equation - Reciprocal lattice - Crystal Defects- point, line and surface defects. (10)

### SEMICONDUCTORS AND THEIR PROPERTIES

Band model of semiconductors - carrier concentrations in intrinsic and extrinsic semiconductors - Fermi level - variation of conductivity and mobility with temperature - law of mass action. Hall effect - Hall coefficients for intrinsic and extrinsic semiconductors - determination of Hall constant - Hall effect devices. (9)

### DIELECTRIC AND OPTICAL PROPERTIES

Static dielectric constant, electronic, ionic and orientation polarizations - Internal or local fields in solid and liquids. Lorentz field in cubic materials - Clausius - Mosotti equation - complex dielectric constant - determination of dipole moment for polar substances - dielectric losses - frequency dependence of electronic, ionic, orientation polarisabilities - optical absorption, luminescence - Thallium activated alkali halides - electro luminescence. (10)

### FERRO ELECTRIC AND PIEZOELECTRIC MATERIALS

General properties - classification of ferro electric materials - dipole theory of ferro electricity - ferro electric domains - applications - piezoelectric materials and applications. (6)

### MAGNETIC PROPERTIES

Diamagnetism, paramagnetism - ferromagnetism - domain theory - magnetic hysteresis, Weissmolecular field theory, Heisenberg's theory - magnetic anisotropy - domain walls - Exchange energy - antiferro magnetism - two sublattice theory - ferrites - properties - structure - magnetic moments - preparation and applications - hard and soft magnetic materials. Garnets magnetic bubbles - magnetic resonance - EPR and NMR. (10)

**TOTAL : 45**

### REFERENCES

1. W.D. Callister, "Materials Science and Engineering: An Introduction", John Wiley & Sons, Inc., 7th Edition, 2007.
2. C. Kittel, "Introduction to Solid State Physics" Wiley Eastern Ltd., 2005.
3. V. Raghavan "Materials Science and Engineering: A First Course", 5th Edition, Prentice Hall of India Pvt. Ltd., 2004.
4. A.J. Dekker, "Solid State Physics", Macmillan and Co., 2000.
5. Michael Shur, "Physics of Semiconductor Devices", Prentice Hall of India, 1995.

# 19MN14 - PHYSICAL AND CHEMICAL SYNTHESIS OF NANOMATERIALS

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

**CO1** : To understand the importance of nanomaterials, its classification and synthesis methods.

**CO2** : To recognize the various fabrication methods available in nanotechnology.

**CO3** : To explain the properties of nanomaterials based on the size and synthesis methodology.

**CO4** : To optimize the synthesis for specific application.

### INTRODUCTION TO NANOMATERIALS

Introduction to nanomaterials, Properties of materials & nanomaterials, role of size in nanomaterials, nanoparticles, semiconducting nanoparticles, nanowires, nanoclusters, quantum wells, conductivity and enhanced catalytic activity compared to the same materials in the macroscopic state. (9)

### CHEMICAL ROUTES FOR SYNTHESIS OF NANOMATERIALS

Chemical precipitation and coprecipitation; Metal nanocrystals by reduction, Sol-gel synthesis; Microemulsions or reverse micelles, micelle formation; Solvo thermal synthesis; Thermolysis routes, Microwave heating synthesis; Sonochemical synthesis; Electrochemical synthesis; Photochemical synthesis, Synthesis in supercritical fluids. (9)

### FABRICATION OF NANOMATERIALS BY PHYSICAL METHODS

Inert gas condensation, Arc discharge, Plasma arc technique, RF plasma, MW plasma, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy, Chemical vapour deposition method and Electrodeposition. (10)

### NANOLITHOGRAPHY

Nanolithography and nano manipulation, E-beam lithography and SEM based nanolithography and nano manipulation, Ion beam lithography, oxidation and metallization. Mask and its application. Deep UV lithography, X-ray based lithography. (9)

### NANOCOMPOSITES

An Introduction: Types of Nanocomposite (i.e. metal oxide, ceramic, glass and polymer based); Core-Shell structured nano composites, Superhard Nanocomposite: Synthesis, applications and milestones. (8)

**TOTAL : 45**

### REFERENCES

1. G. A. Ozin, A. C. Aresnault, L. Cademartiri, *Nanochemistry: A chemical approach to nanomaterials*, RSC Publishing, 2008.
2. Mark James Jackson, *Microfabrication and Nanomanufacturing*. CRC Press; 1 edition, 2005.
3. C. N. R. Rao, Achim Müller, Anthony K. Cheetham, *Chemistry of nanomaterials: Synthesis, properties and applications*, Wiley, 2004.
4. G. Schmidt, Wiley Weinheim, *Nanoparticles: From Theory to Applications*, Wiley, 2010.
5. Darren Goodchild, Alexei Bogdanov; Simon Wingar, Bill Benyon, NakKim; Frank Shepherd, *Fabrication of fine pitch gratings by holography, electron beam lithography and nano-imprint lithography (Proceedings Paper) A Three Beam Approach to TEM Preparation Using In-situ Low Voltage Argon Ion Final Milling in a FIBSEM*.
6. Instrument E L Principe, P Gnauck and P Hoffrogge, *Microscopy and Microanalysis*, 11, 830-831, Cambridge University Press, 2005.
7. Leon L. Shaw, Challapalli Suryanarayana, *Processing & Properties of Structural Nanomaterials*, Wiley, 2003.
8. Geoffrey A Ozin, André Arsenault, Ludovico Cademartiri, *Nanochemistry: A Chemical Approach to Nanomaterials*, Royal Society of Chemistry, Cambridge UK, 2008.
9. P.M. Ajayan, L.S. Schadler, P.V. Braun, *Nanocomposite Science and Technology*, Wiley, New York, 2003.

# 19MN15 - MATERIAL SYNTHESIS AND CHARACTERIZATION LABORATORY - I

L	T	P	C
0	0	4	2

## ASSESSMENT : PRACTICAL

### COURSE OUTCOMES

**CO1** : To synthesize several nanomaterials in different methods in lab scale.

**CO2** : To understand and operate the instruments for material characterization.

**CO3** : To interpret the properties of synthesized nanomaterials by analyzing the results.

### EXPERIMENTS

1. Chemical synthesis of Ag nanoparticles; UV-Visible absorption of the colloidal sol
2. Chemical synthesis of CdS nanoparticles; Optical absorption spectra; Band gap estimation from the band edge.
3. Synthesis of Au nanoparticles by simple chemical method
4. Synthesis of  $\text{Fe}_3\text{O}_4$  nanoparticles by simple reduction method
5. Effect of reducing agent on the synthesis of metal nanoparticles
6. Aqueous to organic phase transfer of Ag and CdS nanoparticles; Confirmation by UV-Visible absorption.
7. Effect of concentration on the synthesis of silver nanoparticles
8. Effect of reducing agent on gold nanoparticles
9. Fabrication of silver nanofilms
10. Synthesis of polyvinyl alcohol fibres by electrospinning method
11. Synthesis of Au and Ag nanoparticles at aqueous-organic liquid interface; UV-visible spectroscopy of the colloidal film; comparison with the corresponding colloidal sol.
12. Sol gel synthesis of  $\text{ZnO}/\text{TiO}_2/\text{CdO}$  nanoparticles.
13. A bioroute to Au nanoparticles.
14. Sol-gel spin coating route to  $\text{SnO}_2$  nanoflms: surface roughness measurement by AFM
15. Hydrothermal synthesis of ZnS Nanorods: Nanorods formation by SEM analysis
16. Preparation of nanofluids.
17. Measurement of stability of nanofluids.
18. Measurement of onset of natural convection in nanofluids.
19. Thermal conductivity measurement of nanofluids.

### REFERENCES

1. Sarit K. Das, Stephen U. Choi, Wenhua Yu, T. Pradeep, *Nanofluids: Science and Technology*, Wiley, 2007.
2. Vincenzo Bianco, Oronzio Manca, Sergio Nardini, Kambiz Vafai, *Heat Transfer Enhancement with Nanofluids*, CRC Press, 2017.
3. Amy S., *Thermal Energy Storage Using Phase Change Materials: Fundamentals and Applications* Fleischer, Springer, 2015.
4. Mohsen Sheikholeslami and Davood Domairry Ganji, *Applications of Nanofluid for Heat Transfer Enhancement*, Elsevier, 2017.
5. S.M. Sohel Murshed, Carlos Nieto de Castro, *Nanofluids: Synthesis, Properties and Applications*, Nova Science Publishers, 2014.

## LIST OF EQUIPMENT

1. Magnetic Stirrer
2. Hot Air Oven
3. Ultrasonicator
4. Autoclave (55, 108 Litres)
5. Chemical Vapor Deposition (CVD)
6. Spin Coating Unit
7. Sputtering Unit
8. Box Furnace (with Max. Temp 1000 °C)
9. Centrifuge Machine
10. Glove Box
11. Vacuum Oven
12. Deep Freezer
13. Refrigerated Centrifuge
14. Weighing Balance
15. Fume Hood
16. Rotary Evaporator
17. Muffle Furnace
18. Thermal Evaporator
19. FTIR Spectrophotometer
20. UV-Visible Spectrophotometer
21. Fluorescence Spectrophotometer
22. Raman Spectrophotometer
23. Atomic Force Microscopy (AFM)
24. Electrospinning Machine
25. High Performance Liquid Chromatography (HPLC)
26. Scanning Electron Microscopy (SEM) - Centralized facility
27. Ball Mill
28. Natural Convection Apparatus
29. Viscometer
30. Electrolytic Bath set up
31. Packed Bed Column

## 19MN16 - MODELLING AND SIMULATION LABORATORY

L	T	P	C
0	0	4	2

### ASSESSMENT : PRACTICAL

#### COURSE OUTCOMES

- CO1** : *Appreciate the utility of the tools like MATLAB & MS EXCEL in solving real time problems and day to day problems.*
- CO2** : *Demonstrate the usefulness of simulation as a tool for problem solving in business, industry, government, and society.*
- CO3** : *Derive and be able to use explicit and implicit one-step methods (Runge-Kutta).*
- CO4** : *Analyze stability of one-step methods, and know the difference in definition and interpretation of algebraic stability, and the consequences for choice of method.*
- CO5** : *Apply appropriate algorithms to solve selected problems, both manually and by writing computer programs.*

#### EXPERIMENTS

1. MATLAB programme to plot the first four eigen functions of a one - dimensional rectangular potential well with infinite potential barrier.
2. Numerical solution of the Schrodinger wave equation for a rectangular potential well with infinite potential barrier using MATLAB programme.
3. Toy model in molecular electronics: IV characteristics of a single level molecule
4. To determine the lattice constant and lattice angles for atomically resolved STM image of HOPG (Highly Oriented Pyrolytic Graphite using offline Scanning Probe Imaging Processor (SPIP) Software.
5. To determine the surface roughness of raw and processed AFM images of glass, silicon and films made by different methods using offline SPIP software.
6. Simulation of I-V Characteristics for a single Junction circuit with a single quantum Dot using MOSES 1.2 Simulator.
7. Study of Single Electron Transistor using MOSES1.2 Simulator.

## 19MN17 - SEMINAR AND TECHNICAL WRITING

L	T	P	C
0	0	3	1

### ASSESSMENT : PRACTICAL

#### COURSE OUTCOMES

- CO1** : *Ability to participate actively in writing activities (individually and in collaboration) that model effective scientific and technical communication in the workplace.*
- CO2** : *Ability to recognize, explain, and use the rhetorical strategies and the formal elements of these the following the specific genres of technical communication such as technical abstracts, data based research reports, instructional manuals, and technical descriptions.*
- CO3** : *Ability to collect, analyze, document, and report research clearly, concisely, logically, and ethically; understand the standards for legitimate interpretations of research data within scientific and technical communities.*

The students are expected to carry out fundamental theoretical and/or experimental studies, connected with physical properties or on process development studies or a design projects and an oral presentation on the work done. The students should maintain a record of the work done regularly and submit the same periodically for assessment. At the end of the semester, the students must submit a report of the work done in the standard format which will be evaluated by a team of senior faculty members and Head of the Department.

# 19MN21 - PHYSICAL AND CHEMICAL METHODS FOR CHARACTERIZATION OF NANOMATERIALS

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

**CO1** : To recognize the importance of characterization techniques for the synthesized nanomaterial.

**CO2** : To understand the principle behind the working of instruments.

**CO3** : To analyze optical, surface, thermal and structural properties of a material.

**CO4** : To develop knowledge of identifying a suitable characterization for specific application.

### SPECTROSCOPIC CHARACTERIZATION

Introduction to Molecular Spectroscopy and Atomic Spectroscopy-Infrared (IR) Spectroscopy and Applications -UV-Visible Spectroscopy- Principle of operation and application for bandgap measurement - Raman Spectroscopy and CARS Applications  
(9)

### STRUCTURAL CHARACTERIZATION

X-ray diffraction, Small angle X-ray Scattering, Optical Microscope and their description, Scanning Electron Microscopy (SEM), Scanning Probe Microscopy (SPM), TEM and EDAX analysis, Scanning Tunneling Microscopy (STM), Atomic force Microscopy (AFM).  
(10)

### THERMAL ANALYSIS METHODS

Principle and Instrumentation of Thermogravimetry; Differential Thermal Analysis and Differential scanning calorimetry-Importance of thermal analysis for nanostructures.  
(7)

### SURFACE CHARACTERIZATION

X-ray Photoelectron Spectroscopy (XPS), Auger electron spectroscopy, Low Energy Ion Scattering Spectroscopy (LEISS), Secondary Ion Mass Spectroscopy (SIMS), Surface area determination by BET method - Particle size determination by light scattering method, zeta potential.  
(10)

### RESONANCE METHODS

Electron Spin Resonance Spectroscopy; NMR Spectroscopy - Chemical Shifts - Applications of NMR, Dynamic Nuclear Magnetic Resonance, Ferromagnetic Resonance (FMR), Mossbauer Spectroscopy.  
(9)

**TOTAL : 45**

### REFERENCES

1. B. D.Cullity, "Elements of X-ray Diffraction", 4th Edition, Addison Wiley, 1978.
2. M. H.Loretto, "Electron Beam Analysis of Materials", Chapman and Hall, 1984.
3. R.M.Rose, L.A.Shepard and J.Wulff, "The Structure and Properties of Materials", Wiley Eastern Ltd, New Delhi, 1968
4. B.W.Mott, "Micro-Indentation Hardness Testing", Butterworths, London, 1956.

# 19MN22 - PROCESSING AND PROPERTIES OF NANOSTRUCTURED MATERIALS

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : To understand the mechanical properties of nanomaterials.
- CO2** : To recognize the polymer processing techniques.
- CO3** : To know the applications of the processed ceramics, polymers and metals.
- CO4** : To interpret the impact of grain size and temperature dependent nanomaterial properties.

### PROCESSING OF METALS AND ALLOYS

Understanding the various processes from the viewpoints of mechanics and processes: rolling, forging, extrusion, wire drawing, sheet metal forming. (6)

### PROCESSING OF POLYMERS

Special techniques like injection moulding, thermoforming, vacuum and pressure assisted forming. (6)

### PROCESSING OF POWDERS OF METALS AND CERAMICS

Selection and characterization of powders, compacting and sintering; mechanical working. Production of Porous and Dense Composite Components: Metal - polymer - and ceramic - based composites. (8)

### PROCESSING OF STRUCTURAL AND FUNCTIONAL NANOCRYSTALLINE MATERIALS

Properties of nanocrystalline materials used for structural, hydrogen storage, magnetic and catalytic applications; processing techniques; techniques for retaining the nanocrystalline structure in service. (10)

### MICROSTRUCTURE AND PROPERTIES

Properties slightly dependent on temperature and grain size; properties strongly dependent on temperature and grain size; strengthening mechanisms; enhancement of available plasticity; grain size evolution and grain size control; Hall-Petch relation, microstructure - dislocation interactions at low and high temperatures; effects of diffusion on strength and flow of materials; methods of enhancing or retarding diffusion; grain boundary sliding and grain boundary migration; current limitations on approaches based on dislocation theory; possibilities for predictive design. (15)

**TOTAL : 45**

### REFERENCES

1. A. H. Cottrell "The Mechanical Properties of Matter", John Wiley, New York, London, 1964.
2. P. Haasen, "Physical Metallurgy", Cambridge University Press, Cambridge, UK, 1978.
3. G. E. Dieter, adapted by D Bacon, "Mechanical Metallurgy", SI Metric edition, McGraw-Hill, Singapore, 1988.
4. K. A. Padmanabhan, "Mechanical Properties of Nanostructured Materials", Materials Science and Engineering, A 304-306, 200-205, 2001.
5. C. C. Koch, "Nanostructured Materials: Processing, Properties and Applications", 2nd Edition, Ed., 2007.

# 19MN23 - THERMODYNAMICS AND KINETICS

L	T	P	C
3	1	0	4

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : To recollect the basics of statistical thermodynamics for micro and macro states.
- CO2** : To develop criterion for equilibria using classical thermodynamics concepts.
- CO3** : To apply the concepts of statistical thermodynamics and different thermodynamic models to predict thermodynamic properties.
- CO4** : To appraise diffusion laws of mass transfer (in phase transformation) by considering the thermodynamics principles.
- CO5** : To describe different nucleation mechanisms using concepts of thermodynamics.

### INTRODUCTION

Thermodynamic laws, Entropy, Statistical thermodynamics: micro-and macro-states. Unitary and multi-component systems, Gibbs phase rule, phase diagrams relevant to macro systems and for nanoscale materials formation, Phase transitions. **(12)**

### CLASSICAL THERMODYNAMICS

General criterion for equilibrium-chemical potential and Gibbs free energy. Physical phenomena unique to small systems- classical thermodynamics- non-equilibrium statistical mechanics- distinction between standard thermodynamics and the thermodynamics of small systems-thermodynamically instability. **(12)**

### STATISTICAL THERMODYNAMICS

Concepts of probability and Maxwell Boltzmann distribution. Different ensembles and partition functions. Thermodynamic functions using appropriate partition functions. Fermi-Dirac and Bose-Einstein statistics and statistical basis of entropy. Heat capacity of solids. Debye and Einstein models. Thermodynamic functions of ideal gases, translational, vibrational and rotational contributions at different levels of approximation. Application of statistical thermodynamics concepts to ortho para hydrogen internal rotation - calculation of equilibrium constants. **(12)**

### PHASE TRANSFORMATIONS

Fick's laws of diffusion, solution of Fick's second law and its applications, atomic model of diffusion and role of crystal defects, temperature dependence of diffusion coefficient, Kirkendall effect. Thermodynamic considerations: Free energy of alloy phases and free energy-composition curves for binary systems. Nucleation and growth - energy considerations; heterogeneous nucleation, growth kinetics, overall transformation rates. **(12)**

### SOLIDIFICATION

Nucleation and growth from liquid phase, stable interface freezing, cellular and dendrite growth, freezing of ingots, nucleation and grain size, segregation, directional solidification, growth of single crystals. Precipitation from solid solution: Homogeneous and heterogeneous nucleation of precipitates, the aging curve, mechanisms of age hardening, examples from Al-Cu and other alloy systems. Order-disorder Transformation: Examples of ordered structures, long and short-range order, detection of super lattices, influence of ordering on properties. **(12)**

**TOTAL : 60**

### TEXT BOOKS

1. G. M. Barrow, *Physical Chemistry (V Edition), McGraw Hill international Series, 1988.*
2. S. Glasstone, *Thermodynamics for chemists, Affiliated East West Press, 1965.*
3. P. W. Atkins, *Physical Chemistry, Sixth edition, Oxford University Press, 1990.*
4. B. C. McClelland, *Statistical Thermodynamics, Chapman and Hall, 1973.*

5. L. K. Nash, *Elements of classical and statistical thermodynamics*, Addison-Wesley, 1970.
6. M. C. Gupta, *Statistical Thermodynamics*, Wiley Eastern Limited, 1993.
7. J. Rajaram and J. C. Kuriacose, *Thermodynamics for Students of Chemistry*, Shobanlal Nagin Chand Co, 1986.
8. N. D. Smith, *Elementary Statistical Thermodynamics*, Plenum Press, 1982.
9. V. Raghavan, *Solid State Phase Transformations*, Prentice-Hall of India Pvt. Ltd. New Delhi, 1987.
10. D.A. Porter and K.E. Easterling, *Transformations in metals and alloys*, 2nd Edition, CRC Press, 1992.

# 19MN24 - MATERIAL SYNTHESIS AND CHARACTERIZATION

## LABORATORY - II

L	T	P	C
0	0	4	2

### ASSESSMENT : PRACTICAL

### COURSE OUTCOMES

- CO1** : To synthesize several nanomaterials in different methods in lab scale.
- CO2** : To understand and operate the instruments for material characterization.
- CO3** : To interpret the properties of synthesized nanomaterials by analyzing the results.

### EXPERIMENTS

1. Synthesis of cerium zirconium oxide nanoparticle by co-precipitation method.
2. Synthesis of ceria nanofibres by Solvo thermal method.
3. Electrochemical deposition of palladium over graphite electrode coated with CNT.
4. Synthesis of silica nanoparticles using Stober method.
5. Development of a silica sol gel coating on a mica sheet.
6. Synthesis of Iron oxide nanoparticles using co-precipitation method.
7. Synthesis of molybdenum disulfide nanoparticles.
8. Synthesis of titania nano fibers by hydrothermal method.
9. Synthesis of gold nano particles using chemical reduction method.
10. Fabrication and wettability characterization of nanostructured soft polymer surfaces.
11. Temperature measurement using interferometry.
12. Study of burn-out phenomena in nanofluids.
13. Performance study on heat exchangers with nanofluids.
14. Quenching studies in nanofluids.
15. Determination of viscosity of nanofluids.
16. Evaporation studies of nanofluids.
17. Gas absorption studies in nanofluids.
18. Optical properties of nanofluids.
19. Performance study of nanofluids for solar thermal applications.

### REFERENCES

1. T. Pradeep, *A Text book of Nanoscience and Nanotechnology*. Tata McGraw-Hill Education, 2003.
2. P.R. Chandran, M. Naseer, N. Udupa, N. Sandhyarani. *Size controlled synthesis of biocompatible gold nanoparticles and their activity in the oxidation of NADH*. *Nanotechnology*. 8, 23(1), 2011.
3. I.A. Ibrahim, A.A. Zikry, M.A. Sharaf. *Preparation of spherical silica nanoparticles: Stober silica*. *J. Am. Sci.*6(11), 985-9, 2010.
4. X. Chen, S.S. Mao. *Titanium dioxide nanomaterials: synthesis, properties, modifications, and applications*. *Chemical reviews*. 11, 107(7), 2891-959, 2007.
5. Sarit K. Das, Stephen U. Choi, Wenhua Yu, T. Pradeep, *Nanofluids: Science and Technology*, Wiley, 2007.
6. Vincenzo Bianco, Oronzio Manca, Sergio Nardini, Kambiz Vafai, *Heat Transfer Enhancement with Nanofluids*, CRC Press, 2017.

7. Amy S. Fleischer, *Thermal Energy Storage Using Phase Change Materials: Fundamentals and Applications*, Springer, 2015.
8. Mohsen Sheikholeslami and Davood Domairry Ganji, *Applications of Nanofluid for Heat Transfer Enhancement*, Elsevier, 2017.
9. S.M. Sohel Murshed, Carlos Nieto de Castro, *Nanofluids: Synthesis, Properties and Applications*, Nova Science Publishers, 2014.

**List of Equipment : As given in Lab - I**

## 19MN25 - MINI PROJECT

L	T	P	C
		4	2

### ASSESSMENT : PRACTICAL

#### COURSE OUTCOMES

- CO1** : *The students would understand the initiation of a project, their pre-requirements, flowchart preparation, and economic calculation and solution.*
- CO2** : *Conducting experiments to solve complex engineering problems effectively as an individual or team work.*
- CO3** : *Perform as a leader with good ethical principles to meet societal needs in the field of chemical and allied engineering.*

The students are expected to carry out mini project connected with process development studies which will be assigned by the faculty in charge. Progress of the work will be assessed periodically in which the student will give an oral presentation on the work done. The student should maintain a record of the work done regularly and submit them for assessment periodically. At the end of the semester, the students should submit a report of the work done in standard format which will be evaluated by the faculty and subject experts.

## 19MN41 - PROJECT WORK AND VIVA-VOCE

L	T	P	C
			18

### ASSESSMENT : PRACTICAL

#### COURSE OUTCOMES

- CO1** : *Students would be able to design, analyze the data and interpretation of a chemical process and product based system to meet desired needs.*
- CO2** : *Students are provided to work multidisciplinary areas related to Nano Science and Technology.*
- CO3** : *Students are able to work as Nano Science and Technological Professionals, with portfolio ranging from process, data analysis, perform data management and software design, as well as management and administration of entire systems.*

Every candidate individually shall undertake the project work during the fourth semester. Work can be undertaken in an industrial/ research organization or in the Institute in consultation with the faculty guide and the Head of the Department. In case of Project Work at industrial/research organization, the same shall be jointly supervised by a faculty guide and an expert from the organization. The students should maintain a record of the work done regularly and submit them for assessment periodically. At the end of the semester, the students should submit a report of the work done in standard format which will be evaluated by the faculty and subject experts.

# 19MNE01 - NUMERICAL METHODS AND COMPUTER PROGRAMMING

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : Demonstrate understanding of common numerical methods and how they are used to obtain approximate solutions to otherwise intractable mathematical problems.
- CO2** : Apply numerical methods to obtain approximate solutions to mathematical problems.
- CO3** : Derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations, and the solution of differential equations.
- CO4** : Analyse and evaluate the accuracy of common numerical methods.
- CO5** : Apply appropriate algorithms to solve selected problems, both manually and by writing computer programs.

### APPROXIMATION METHODS AND ROOTS OF EQUATIONS

Accuracy and precision, Truncation and round-off errors. Bracketing Methods (false position, bisection), Iteration Methods (Newton-Raphson and secant). (9)

### SYSTEMS OF LINEAR ALGEBRAIC EQUATIONS AND CURVE FITTING

Gauss elimination, matrix inversion and LU decomposition methods. Curve fitting: Least squares regression, Linear, multiple linear and nonlinear regressions, Cubic spline. (9)

### INTERPOLATION METHODS AND FOURIER APPROXIMATION

Newton's divided difference and Lagrange interpolating polynomials. Fourier approximation: Curve fitting with oscillatory functions, Frequency and time domains, Discrete Fourier and Fast Fourier transforms. (9)

### DIFFERENTIATION AND INTEGRATION

Divided difference method for differentiation, Newton-Cotes formula, Trapezoidal and Simpson's rules, Romberg and Gauss quadrature methods. Euler's method and its modifications, Runge-Kutta methods, Boundary value and Eigen value problems. (9)

### PARTIAL DIFFERENTIAL EQUATIONS

Finite difference equations, Elliptic equations, Laplace's equation and solutions, Parabolic equations, Solution of the heat conduction equation. Finite element method: General approach, Application to 1-dimensional and 2-dimensional problems. (9)

**TOTAL : 45**

### REFERENCES

1. J.B. Scarborough, John Hopkins, Numerical Mathematical Analysis, 1966.
2. S.S. Sastry, Introductory Methods of Numerical Analysis, Prentice Hall of India, 1983
3. S.C. Chapra and R.C. Canale, Numerical Methods for Engineering, McGraw-Hill, 1989.
4. Numerical Methods for Scientists and Engineers, Prentice Hall of India, 1988.
5. Nathan P-Ida and J.P.A. Bastos, Electromagnetics and Calculation of Fields, Springer-Verlag, 1992.
6. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, Wiley Eastern, 1992.
7. J.H. Rice, Numerical Methods, Software and Analysis, McGraw-Hill, 1983.

# 19MNE02 - NANOSCALE INTEGRATED COMPUTING

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : To understand the quantum approach behind the nano computing.  
**CO2** : To interpret the theory behind quantum computing.  
**CO3** : To relate the various synthesized nano structures for novel applications.  
**CO4** : To develop knowledge on applications of nano-computing in medical care.

### AN INTRODUCTION TO NANOCOMPUTING

Micro computing era - Transistor as a switch, difficulties with transistors at the nanometer scale - Nanoscale devices - Molecular devices - Nanotubes - Quantum dots - Wave computing - Quantum computing. **(9)**

### QUANTUM COMPUTING

Reversible computations - Quantum computing models - Complexity bounds for quantum computing - Quantum compression - Quantum error correcting codes - Quantum cryptography - Computing with quantum dot cellular automata - Quantum dot cellular automata cell - Ground state computing - Clocking - QCA addition - QCA multiplication - QCA memory - 4-bit processor. **(9)**

### SPIN-WAVE ARCHITECTURES

Spin wave crossbar - Spin wave reconfigurable mesh - Spin wave fully interconnected cluster - Multi-scale Hierarchical architecture - Spin wave based logic devices - Logic functionality - Parallel computing with spin waves - Parallel algorithm design techniques - Parallel routing and broadcasting - On-Spin wave crossbar - On-Spin wave reconfigurable mesh - On-Spin wave fully interconnected cluster. **(9)**

### MOLECULAR COMPUTING

Switching and memory in molecular bundles - molecular bundle switches - Circuit and architectures in molecular computing - Molecular grafting for silicon computing - Molecular grafting on intrinsic silicon nanowires - Self-assembly of CNTs. **(9)**

### COMPUTATIONAL TASKS IN MEDICAL NANOROBOTICS

Medical Nanorobot designs - Microbivores - Clotocytes - Chromalocytes - Common functions requiring onboard computation - Nanorobot control protocols: Operation protocols - Biocompatibility protocols - Theater protocols - Nanoscale image processing: Labeling problem - Convex Hull problem - Nearest neighbor problem. **(9)**

**TOTAL : 45**

### REFERENCES

1. M.A. Nielsen, L. Isaac, Chuang, *Quantum computation and quantum information?*, Cambridge University Press, 2000.
2. A.K. Jain, *Fundamentals of Digital Image Processing*, Prentice-Hall, 1988.
3. D.K. Schroder, *Semiconductor Material and Device Characterization*, New York, 2006.
4. C. Zhou, *New Haven, Atomic and Molecular wires*, Yale University Press, 1999.

# 19MNE03 - NANOTECHNOLOGY IN ENERGY CONVERSION AND STORAGE

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : To understand the need for renewable energy resources.
- CO2** : To recognize the challenges in renewable energy production.
- CO3** : To explain the principle behind using nanotechnology for energy production.
- CO4** : To develop knowledge on bio-nanotechnology based energy production methods.

### INTRODUCTION

Nanotechnology for sustainable energy- Energy conversion process, indirect and direct energy conversion-Materials for light emitting diodes-batteries-advanced turbines-catalytic reactors-capacitors-fuel cells. (9)

### RENEWABLE ENERGY TECHNOLOGY

Energy challenges, development and implementation of renewable energy technologies - nanotechnology enabled renewable energy technologies -Energy transport, conversion and storage- Nano, micro, and poly crystalline and amorphous Si for solar cells, Nano-micro Si-composite structure, various techniques of Si deposition. (9)

### MICRO FUEL CELL TECHNOLOGY

Micro-fuel cell technologies, integration and performance for micro-fuel cell systems -thin film and microfabrication methods - design methodologies - micro-fuel cell power sources. (9)

### MICROFLUIDIC SYSTEMS

Nano-electromechanical systems and novel microfluidic devices - nano engines - driving mechanisms - power generation - microchannel battery - micro heat engine (MHE) fabrication - thermocapillary forces -Thermocapillary pumping (TCP) - piezoelectric membrane. (9)

### HYDROGEN STORAGE METHODS

Hydrogen storage methods - metal hydrides - size effects - hydrogen storage capacity -hydrogen reaction kinetics - carbon-free cycle- gravimetric and volumetric storage capacities - hydriding / dehydriding kinetics -high enthalpy of formation - and thermal management during the hydriding reaction. (9)

**TOTAL : 45**

### REFERENCES

1. J. Twidell, T. Weir, *Renewable Energy Resources*, E & F N Spon Ltd, London, 1986.
2. Martin A. Green, *Solar cells: Operating principles, technology and system applications*, Prentice Hall Inc, Englewood Cliffs, NJ, USA, 1981.
3. H.J. Moller, *Semiconductor for solar cells*, Artech House Inc, MA, USA, 1993.
4. Ben G. Streetman, *Solis state electronic device*, Prentice Hall of India Pvt Ltd., New Delhi, 1995.
5. M.A. Kettani, *Direct energy conversion*, Addison Wesley Reading, 1970.
6. Linden, *Hand book of Batteries and fuel cells*, Mc Graw Hill, 1984.
7. Hoogers, *Fuel cell Technology Handbook*, CRC Press, 2003.
8. Vielstich, *Handbook of Fuel Cells: Fuel cell technology and applications*, Wiley, CRC Press, 2003.

# 19MNE04 - SEMICONDUCTOR NANOPARTICLES

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : To recognize the importance of semiconductor nanoparticles.
- CO2** : To understand the principle behind the working of semiconductor devices.
- CO3** : To familiarize with the available synthesis methodologies of semiconductor nanomaterials.
- CO4** : To develop knowledge on future applications of these nanomaterials.

### SEMICONDUCTOR NANOPARTICLES

Size-dependant physical properties, Melting point, solid state phase transformations, excitons, band-gap variations-quantum confinement, effect of strain on band-gap in epitaxial quantum dots. The p-n junction and the bipolar transistor; metal semiconductor and metal-insulator. (9)

### SEMICONDUCTOR JUNCTIONS

Semiconductor junctions; field-effect transistors, MOSFETs, CMOS: hetero structures, high-electron-mobility devices, HEMTs, Quantum Hall effect, Introduction to single electron transistors (SETs): quantum dots, single electron effects, Coulomb blockade. (9)

### SYNTHESIS

Synthesis, Cluster compounds, quantum-dots from MBE and CVD, wet chemical methods, reverse micelles, electro-deposition, pyrolytic synthesis, self-assembly strategies. (9)

### APPLICATIONS OF SEMICONDUCTOR NANOPARTICLES

Optical luminescence and fluorescence from direct band gap semiconductor nanoparticles, surface-trap passivation in core-shell nanoparticles, carrier injection, polymer-nanoparticle, LED and solar cells, electroluminescence, barriers to nanoparticle lasers, doping nanoparticles, Mn-Zn-Se phosphors, light emission from indirect semiconductors, light emission from Si nanodots. (9)

### NANOWIRES

Semiconductor nanowires, Fabrication strategies, quantum conductance effects in semiconductor nanowires, porous silicon, nanobelts, nanoribbons, nanosprings. (9)

**TOTAL : 45**

### REFERENCES

1. H.S. Nalwa, *Encyclopedia of Nanotechnology*, American Scientific Publishers, 1st edition, 2003.
2. Bharat Bhusan, *Springer Handbook of Nanotechnology*, 3rd Edition, 2010
3. A.A. Balandin, K.L. Wang, *Handbook of Semiconductor Nanostructures and Nanodevices, Vol 1*, American Scientific Publishers, 2006.
4. C. Guozhong, *Nanostructures and Nanomaterials - Synthesis, Properties and Applications*, Imperial College Press; 1st edition, 2004.

# 19MNE05 - NANO DEVICES AND SENSORS

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : To understand the working principle of quantum devices.
- CO2** : To describe the characteristics of emerging quantum devices.
- CO3** : To relate this theoretical approach for developing a sensor for real time application.
- CO4** : To develop knowledge on application of these sensors for clinical diagnosis.

### QUANTUM DEVICES

Quantum Electronic devices - Electrons in mesoscopic structures - Short channel, MOS Transistor - split Gate Transistor - Electron wave transistor - Electron spin transistor - Quantum Dot array - Quantum computer- Bit and Qubit. Carbon Nanotube based logic gates, optical devices. Connection with quantum dots, quantum wires, and quantum wells. (9)

### TUNNELING DEVICES

Tunneling element - Tunnel Effect and Tunneling Elements-Tunneling Diode - Resonant Tunneling Diode - Three -Terminal Resonant Tunneling Devices-Technology of RTD-Digital circuits design based on RTDs - Basics Logic Circuits - Single Electron Transistor(SET) -Principle - Coulomb Blockade- Performance - Technology- Circuit Design- Logic and Memory Circuits - SET adder as an Example of a Distributed Circuit. (9)

### SUPERCONDUCTING DEVICES AND PHOTONICS

Basics - Macroscopic model- Super conducting switching Devices - Cryotron- Josephson Tunneling Devices- Elementary circuits - Associative or Content - Addressable Memory -SQUID - Flux Quantum device -LC -Gate - Magnetic Flux Quantum - Quantum cellular Automata- Quantum computer with Single Flux devices - SFQD- RSFQD - Application of superconducting devices. (9)

### MICRO AND NANOSENSORS

Fundamentals of sensors, biosensor, micro fluids, Packaging and characterization of sensors, Method of packaging at zero level, dye level and first level. Sensors for aerospace and defense: Accelerometer, Pressure Sensor, Night Vision System, Nanotweezers, nano-cutting tools, Integration of sensor with actuators and electronic circuitry. (9)

### BIOSENSORS

Clinical Diagnostics, generation of biosensors, immobilization, characteristics, applications, conducting Polymer based sensor, DNA Biosensors, optical sensors. Biochips. Metal Insulator Semiconductor devices, molecular electronics, information storage, molecular switching, Schottky devices. (9)

**TOTAL : 45**

### REFERENCES

1. K. Goser, P. Glosekotter and J. Dienstuhl, "Nanoelectronics and Nanosystems-From Transistors to Molecular Quantum Devices", Springer, 2004.
2. HerveRigneault, Jean-Michel Lourtioz, Claude Delalande, Ariel Levenson, "Nanophotonics", Wiley-ISTE, 2006.
3. W.R.Fahrner, "Nanotechnology and Nanoelectronics - Materials, Devices and Measurement Techniques" Springer, 2006
4. H. Meixner, Sensors: Micro & Nanosensors, Sensor Market trends (Part 1&2), VchVerlagsgesellschaftMbh, 1995.
5. Ping Sheng, Nanoscience & Technology: Novel structure and phenomena, CRC Press, 2003.
6. Michael Rieth, Nano Engineering in Science & Technology: An introduction to the world of nano design, World Scientific Publishing Company, 2003.
7. Tai-Ran Hsu, "MEMS & Microsystems Design and Manufacture", Tata McGraw-Hill publication, 2001.
8. P. Rai-Choudhury, "MEMS and MOEMS Technology and Applications", PHI learning Pvt. Ltd., 2009.
9. Mohamed Gad-el-Hak, "The MEMS Handbook", CRC Press, 2002.

# 19MNE06 - POLYMERS AND NANOCOMPOSITES

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : To understand the chemistry of the polymers.
- CO2** : To explain the types of polymerization and its characteristics.
- CO3** : To recognize the fundamentals of polymer based composites.
- CO4** : To understand the polymer processing methods and its application.

### POLYMER CHAINS AND THEIR CHARACTERIZATION

The science of large molecules - Basic concepts of polymer science. History of macromolecular science, molecular forces and chemical bonding in polymers. Polymer solutions. Criteria for polymer solubility, Conformations of dissolved polymer chains, Thermodynamics of polymer solutions, Phase separation in polymer solutions. (9)

### POLYMERIZATION TECHNIQUES

Step-reaction (Condensation) polymerization - Classification of polymers and polymerization mechanisms, chemistry of stepwise polymerization, kinetics and statistics of linear stepwise polymerizations. Radical chain (Addition) polymerization - chemistry of vinyl polymerization, laboratory methods in vinyl polymerization, steady state kinetics of vinyl radical polymerization. Ionic and coordination chain (Addition) polymerization - chemistry of non-radical chain polymerization, cationic polymerization, anionic polymerization, coordination polymerization. copolymerization - Kinetics of copolymerization, composition of copolymers, chemistry of copolymerization. (9)

### FUNDAMENTALS OF POLYMER COMPOSITES

Types of composites reinforced thermoplastics, thermosets, reinforcement of elastomers, materials and types of reinforcements, Thermosetting and thermo plastic materials- their curing characteristics, FRTP pellets, their production, processing, fillers and additives. Mechanical, electrical, thermal and viscoelastic properties of composites as determined by composition and its effect on processing. (10)

### COMPOSITES AND FABRICATION PROCESSES

Pressure bag/vacuum bag moulding, compression moulding, filament winding, autoclave molding, centrifugal casting, pultrusion, injection moulding. Application of cellular plastics, effects on properties, methods of production, types of products and applications. (9)

### POST PROCESSING METHODS

Cutting, trimming, machining, water jet cutting, abrasive jet cutting, laser cutting, joining, mechanical and adhesive points, painting, coating and other processes. (9)

**TOTAL : 45**

### TEXT BOOKS

1. F.W. Billmeyer, *Textbook of Polymer Science, Third Edition, Wiley Interscience, 1984.*
2. E. Charles, Jr. Carraher, *Seymour/Carraher's polymer chemistry, Seventh Edition, CRC Press, 2012.*
3. G. Lubin, *Von Nostrand Rein Hold, Handbook of Composites, New York 1982.*
4. J.G. Mohr, *SPI Handbook of Technology and Engineering of Reinforced Plastics/Composites, Second Edition, New York, Van Nostrand Rein- hold Company.1973.*

### REFERENCES

1. J.R. Fried, *Polymer Science and Technology, Second Edition, Prentice Hall of India Pvt. Ltd., 2003.*
2. M.S. Bhatnagar, *A Textbook of Polymers, Vol. 2, S.Chand and Company Ltd., 2012.*

# 19MNE07 - THIN FILM TECHNOLOGY

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : To describe the various film deposition techniques.
- CO2** : To understand the surface chemistry of the thin films on the substrate.
- CO3** : To familiarize with the available characterization techniques for thin film deposition.
- CO4** : To explain the mechanical properties of the films.

### THIN FILM DEPOSITION TECHNIQUES

Introduction - Kinetic theory of gases - Physical vapour deposition techniques - Physics and Chemistry of Evaporation - Thermal evaporation - Pulsed laser deposition - Molecular beam epitaxy - Sputtering deposition - DC, RF, Magnetron, Ion beam and reactive sputtering - Chemical methods - Thermal CVD - Plasma enhanced CVD - Spray Pyrolysis - Sol Gel method - Spin and Dip coating - Electro plating and Electroless plating - Deposition mechanisms. (9)

### CHARACTERIZATION TECHNIQUES

Surface analysis techniques - Auger Electron spectroscopy - Photoelectron Spectroscopy - Secondary Ion Mass Spectroscopy - X-ray Energy Dispersive Analysis - Rutherford Backscattering spectroscopy - Imaging Analysis Techniques - Scanning Electron Microscopy - Transmission Electron Microscopy - Optical analysis Techniques - Ellipsometry - Fourier Transform Infrared Spectroscopy - Photoluminescence Spectroscopy. (9)

### ADSORPTION AND DIFFUSION IN THIN FILMS

Physisorption - Chemisorption - Work function changes induced by adsorbates - Two dimensional phase transitions in adsorbate layers - Adsorption kinetics - Desorption techniques. Fundamentals of diffusion - Grain Boundary Diffusion - Thin Film Diffusion Couples - Inter Diffusion - Electromigration in thin films - Diffusion during film growth. (9)

### STRESS IN THIN FILMS

Origin of Thin film stress - Classifications of stress - Stress in epitaxial films - Growth Stress in polycrystalline films - Correlation between film stress and grain structure - Mechanisms of stress evolution - film stress and substrate curvature - Stoney formula - Methods of curvature measurement - Scanning laser method. (9)

### MODIFICATION OF SURFACES AND FILMS

Introduction - Laser and their Interactions with Surfaces - Laser modification effects and applications - Laser sources and Laser scanning methods - Thermal analysis of Laser annealing - Laser surface alloying - Ion implantation effects in solids - Energy loss and structural modification - compositional modification - Ion beam modification phenomena and applications. (9)

**TOTAL : 45**

### REFERENCES

1. Amy E. Wendt, *Thin Films - High density Plasmas, Volume 27, Springer Publishers, 2006.*
2. Rointan F. Bunshah, *Hand Book of Deposition technologies for Thin Films and coatings by Science, Technology and Applications, Second Edition, Noyes Publications, 1993.*
3. Milton Ohring, *Materials Science of Thin films Published by Academic Press Limited, 1991.*
4. L.B. Freund and S.Suresh, *Thin Film Materials, 2003.*
5. Hans Luth, *Solid surfaces, Interfaces and Thin Films' 4th edition, Springer Publishers, 2010.*
6. Harald Ibach, *Physics of Surfaces and Interfaces, Springer Publishers, 2006.*

## 19MNE08 - NEW SEPARATION TECHNIQUES

L	T	P	C
3	0	0	3

### ASSESSMENT : THEORY

#### COURSE OUTCOMES

**CO1** : To enhance the student understands of basic concepts of modern separation processes

**CO2** : To help the student to indicate the analytical separation.

**CO3** : To produce ability to differentiate the different separation process.

**CO4** : To impart ability to identify the process to be use for the given conditions.

**CO5** : To increase the ability to interpret and analyze new separation problems successfully.

#### MEMBRANE SEPARATIONS

Types and choice of membranes, their merits, commercial, pilot plant polarization of membrane processes and laboratory membrane permeators, dialysis, reverse osmosis, ultra filtration, Concentration and economics of membrane operations, Design controlling factors. (9)

#### SEPARATION BY SORPTION TECHNIQUES

Types and choice of adsorbents, chromatographic techniques, Types, Retention theory mechanism, Design controlling factors ion exchange chromatography equipment and commercial processes, recent advances and economics. (9)

#### IONIC SEPARATIONS

Controlling factors, applications, Theory mechanism and - equipment for electrophoresis, di-electrophoresis and electro dialysis - commercial applications - Design considerations. (9)

#### THERMAL SEPARATION

**Thermal diffusion** : Basic rate law, phenomenological theories of thermal diffusion for gas and liquid mixtures, Equipments design and applications. Zone melting: Equilibrium diagrams, Controlling factors, Apparatus and applications. (9)

#### OTHER TECHNIQUES

Adductive crystallization molecular addition compounds, Clathrate compounds and adducts, Equipment, Applications, Economics and commercial processes. Foam Separation: Surface adsorption, Nature of foams, Apparatus, Applications, and Controlling factors. (9)

**TOTAL : 45**

#### TEXT BOOKS

1. H.M. Schoen, *New Chemical Engineering Separation Techniques*, Wiley Interscience, New York, 1972.
2. C.J. King, *Separation Processes*, Tata McGraw Hill, New Delhi, 1982.

#### REFERENCES

1. B. Sivasankar, *Bioseparations: Principles and Techniques*, Prentice Hall of India Pvt. Ltd, New Delhi, 2005.
2. H.R.C. Pratt, *Counter-Current Separation Processes*, Elsevier, Amsterdam, 1967.

## 19MNE09 - CRYSTAL GROWTH TECHNIQUES

L	T	P	C
3	0	0	3

### ASSESSMENT : THEORY

#### COURSE OUTCOMES

**CO1** : To understand the thermodynamic principles involved in crystal growth.

**CO2** : To describe the kinetics of nucleation synthesis process.

**CO3** : To understand the step by step process involved in nano material synthesis.

**CO4** : To provide a key knowledge for optimization of synthesis procedure.

#### CRYSTAL GROWTH THEORY

Introduction - Nucleation - Gibbs - Thomson equation for melt and solution - kinetic theory of nucleation - Limitation of classical nucleation - Rate of nucleation - Different shapes of nucleus - spherical, cap shaped and cylindrical. (9)

#### GROWTH FROM MELT

Bridgeman method - Kyropolous method - Czochralski method - Verneuil method - Zone melting method. Growth from flux - Slow cooling method - Temperature difference method - High pressure method - Solvent evaporation method - Top seeded solution growth. (9)

#### GROWTH FROM VAPOR PHASE

Physical vapor deposition - Chemical vapor transport - Open and Closed system - Thermodynamics of chemical vapor deposition process - Physical and Thermo-chemical factors affecting growth process. (9)

#### GROWTH FROM SOLUTIONS

Solvent and solutions - Solubility - Preparation of a solution - Saturation and supersaturation - Measurement of supersaturation - Expression for supersaturation - Low temperature growth solution growth - Slow cooling method - Manson jar method - Evaporation method - Temperature gradient method - Electro crystallization. Growth from gels - Experimental methods - Chemical reaction method - Reduction method - Complex decomposition method - Solubility reduction method - Growth by hydrothermal method. (9)

#### EPITAXY

Vapor phase epitaxy - Liquid phase epitaxy - Molecular beam epitaxy - Atomic layer epitaxy - Electro-epitaxy - Metal organic epitaxy - Chemical beam epitaxy. (9)

**TOTAL : 45**

#### REFERENCES

1. K. Sangwal, *Elementary Crystal Growth 1st Ed.*, Saan Publisher, UK, 1994.
2. M.M. Faktor, I. Garet, *Growth of crystal from vapor, 1st Ed.*, Chapman and Hall, 1988.
3. P. Santhana Ragavan, P. Ramasamy, *Crystal growth and process, 1st Ed.*, KRU Publications, 2000.
4. P. Ramasamy, *ISTE Summer School Lecture Notes, Crystal Growth Centre, Anna University, Chennai, (1991).*
5. J.C. Brice, *Crystal growth process, 1st Ed.*, John Wiley Publications, New York, 1986.
6. A.A. Chernov, *Modern Crystallography: III - Crystal Growth', 1st Ed.*, Springer series in Solid State, New York, 1984.

# 19MNE10 - NANOBIO TECHNOLOGY

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

**CO1** : To understand the basics and fundamental principles of nanobiotechnology.

**CO2** : To analyze the interaction between biomolecules and nanoparticle surface.

**CO3** : To optimize the synthesis procedure of nano-biomaterials.

**CO4** : To analyze the various DNA based nanostructures.

### BIONANOMACHINES AND THEIR BASICS

Negligible gravity and inertia, atomic granularity, thermal motion, water environment and their importance in bionanomachines. The role of proteins- amino acids- nucleic acids- lipids and polysaccharides in modern biomaterials. Overview of natural Bionanomachines: Thymidylate Synthetase, ATP synthetase, Actin and myosin, Opsin, Antibodies and Collagen. (9)

### SYNTHESIS OF BIOMOLECULES & INTERPHASE SYSTEMS

Recombinant Technology, Site-directed mutagenesis, Fusion Proteins. Quantum Dot structures and their integration with biological structures. Molecular modeling tools: Graphic visualization, structure and functional prediction, Protein folding prediction and the homology modeling, Docking simulation and Computer assisted molecular design. Interphase systems of devices for medical implants - Microfluidic systems - Microelectronic silicon substrates - Nano-biometrics - Introduction - Lipids as nano-bricks and mortar: self-assembled nanolayers. (9)

### FUNCTIONAL PRINCIPLES OF NANOBIO TECHNOLOGY

Information driven nanoassembly, Energetic, Role of enzymes in chemical transformation, allosteric motion and covalent modification in protein activity regulation, Structure and functional properties of Biomaterials, Bimolecular motors: ATP Synthetase and flagellar motors, Traffic across membranes: Potassium channels, ABC Transporters and Bacteriorhodopsin, Bimolecular sensing, Self-replication, Machine-Phase Bionanotechnology Protein folding; Self-assembly, Self-organization, Molecular recognition and Flexibility of biomaterials. (9)

### PROTEIN AND DNA BASED NANOSTRUCTURES

Protein based nanostructures building blocks and templates - Proteins as transducers and amplifiers of biomolecular recognition events - Nanobioelectronic devices and polymer nanocontainers - Microbial production of inorganic nanoparticles - Magnetosomes .DNA based nanostructures - Topographic and Electrostatic properties of DNA and proteins - Hybrid conjugates of gold nanoparticles - DNA oligomers - Use of DNA molecules in nanomechanics and computing. (9)

### APPLICATIONS OF NANOBIO TECHNOLOGY

Semiconductor (metal) nanoparticles and nucleic acid and protein based recognition groups - Application in optical detection methods - Nanoparticles as carrier for genetic material - Nanotechnology in agriculture - Fertilizer and pesticides. Designer proteins, Peptide nucleic acids, Nanomedicine, Drug delivery, DNA computing, Molecular design using biological selection, Harnessing molecular motors, Artificial life, Hybrid materials, Biosensors, Future of Bionanotechnology. (9)

**TOTAL : 45**

### REFERENCES

1. C.M. Niemeyer, C.A. Mirkin, *Nanobiotechnology: Concepts, Applications and Perspectives*, Wiley VCH, 2004.
2. T. Pradeep, *Nano: The Essentials*, McGraw - Hill Education, 2007.
3. Challa, S.S.R. Kumar, Josef Hormes, Carola Leuschaer, *Nanofabrication Towards Biomedical Applications, Techniques, Tools, Applications and Impact Wiley-VCH, 2005.*
4. Nicholas A. Kotov, *Nanoparticle Assemblies and Superstructures* CRC, 2006.
5. David S Goodsell, *"Bionanotechnology"* John Wiley & Sons, 2004.

# 19MNE11 - BIOCHEMICAL ENGINEERING

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : To understand and use the basic principles of biology and biochemistry to successfully design and operate a biochemical process.
- CO2** : Students develop an understanding of the science and engineering principles underlying modern industrial practices in bioprocessing.
- CO3** : To understand the factors effecting cell growth and to design and operate various bioreactors.
- CO4** : Ability to apply knowledge of various unit operations for biochemical processes and in microbiological systems.

### INTRODUCTION

Structure of microbial cells - classes of microbes - chemicals of life - cellular metabolism and energetic. (9)

### KINETICS OF ENZYMES

Kinetics of substrate - Product and Biomass yield. Kinetics of enzyme catalyzed reactions. (9)

### SEPARATION OF ENZYMES

Characteristics, isolation and uses of enzymes. Aeration and agitation in biochemical reactors, Media and Air sterilization. (9)

### FERMENTATION PROCESSES

Scale up of fermentation operation. Measurement, control and product recovery in fermentation processes. (9)

### TRANSPORT IN MICROBIAL SYSTEM

Transport phenomena in microbial systems: Gas - Liquid mass transfer in microbial systems. Mass transfer across free surfaces, scaling of mass transfer equipment, factors affecting mass transfer coefficients. (9)

**TOTAL : 45**

### TEXT BOOKS

1. J.E. Bailey, D.F. Ollis, *Biochemical Engineering Fundamentals, Second Edition, McGraw Hill, International student edition, 1986.*
2. Schuler, Kargi, *Bioprocess Engineering, Prentice Hall of India Pvt. Ltd, New Delhi, 1992.*

### REFERENCE

1. S. Aiba, A.E. Humphrey, N.R. Millis, *Biochemical Engineering, Second Edition, Academic Press, 1973.*

# 19MNE12 - INDUSTRIAL NANOTECHNOLOGY

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

**CO1** : To understand the principle and working of nano-electronic devices and its application.

**CO2** : To identify the application of nanotechnology in pharma industries.

**CO3** : To analyze the role of various nanostructures in chemical and agricultural industries.

**CO4** : To grasp the role of nanofibers in textile industries.

### NANOTECHNOLOGY IN ELECTRICAL AND ELECTRONICS INDUSTRY

Advantages of nano electrical and electronic devices -Electronic circuit chips - Lasers - Micro and Nano-Electromechanical systems - Sensors, Actuators, Optical switches, Bio-MEMS -Diodes and Nano-wire Transistors - Data memory -Lighting and Displays - Filters (IR blocking) - Quantum optical devices - Batteries - Fuel cells and Photo-voltaic cells - Electric double layer capacitors - Lead-free solder - Nanoparticle coatings for electrical products. (9)

### NANOTECHNOLOGY IN BIOMEDICAL AND PHARMACEUTICAL INDUSTRY

Nanoparticles in bone substitutes and dentistry - Implants and Prosthesis - Reconstructive Intervention and Surgery - Nanorobotics in Surgery - Photodynamic Therapy - Nanosensors in Diagnosis- Neuro-electronic Interfaces - Protein Engineering - Drug delivery - Therapeutic applications. (9)

### NANOTECHNOLOGY IN CHEMICAL INDUSTRY

Nanocatalysts - Smart materials - Heterogenous nanostructures and composites - Nanostructures for Molecular recognition (Quantum dots, Nanorods, Nanotubes) - Molecular Encapsulation and its applications - Nanoporous zeolites - Self-assembled Nanoreactors - Organic electroluminescent displays. (9)

### NANOTECHNOLOGY IN AGRICULTURE AND FOOD TECHNOLOGY

Nanotechnology in Agriculture -Precision farming, Smart delivery system - Insecticides using nanotechnology - Potential of nano-fertilizers - Nanotechnology in Food industry - Packaging, Food processing - Food safety and bio-security - Contaminant detection - Smart packaging. (9)

### NANOTECHNOLOGY IN TEXTILES AND COSMETICS

Nanofibre production - Electrospinning - Controlling morphologies of nanofibers - Tissue engineering application - Polymer nanofibers - Nylon-6 nanocomposites from polymerization - Nano-filled polypropylene fibers - Bionics- Swim-suits with shark-skin-effect, Soil repellence, Lotus effect - Nano finishing in textiles (UV resistant, antibacterial, hydrophilic, self-cleaning, flame retardant finishes) - Modern textiles (Lightweight bulletproof vests and shirts, Colour changing property, Waterproof and Germ proof, Cleaner kids clothes, Wired and Ready to Wear)

Cosmetics - Formulation of Gels, Shampoos, Hair-conditioners (Micellar self-assembly and its manipulation) - Sun-screen dispersions for UV protection using Titanium oxide - Color cosmetics. (9)

**TOTAL : 45**

## REFERENCES

1. Mark A. Ratner, Daniel Ratner, *Nanotechnology: A Gentle Introduction to the Next Big Idea*, Pearson, 2003.
2. Bharat Bhushan, *Springer Handbook of Nanotechnology*, Barnes & Noble, 2004.
3. Neelina H. Malsch (Ed.), *Biomedical Nanotechnology*, CRC Press, 2005.

4. *Udo H. Brinker, Jean-Luc Mieusset (Eds.), Molecular Encapsulation: Organic Reactions in Constrained Systems, Wiley Publishers, 2010.*
5. *Jennifer Kuzma and Peter VerHage, Nanotechnology in agriculture and food production, Woodrow Wilson International Center, 2006.*
6. *Lynn J. Frewer, WillehmNorde, R. H. Fischer, W. H. Kampers, Nanotechnology in the Agri-food sector, Wiley-VCH Verlag, 2011.*
7. *P.J. Brown and K. Stevens, Nanofibers and Nanotechnology in Textiles, Woodhead Publishing Limited, Cambridge,2007.*
8. *Y.W. Mai, Polymer Nano composites, Woodhead publishing, 2006.*
9. *W.N. Chang, Nanofibres fabrication, performance and applications, Nova Science Publishers Inc, 2009.*

# 19MNE13 - NANO POLLUTION AND E-WASTE MANAGEMENT

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

**CO1** : To understand the principle and working of nanoparticle analyzer.

**CO2** : To identify the impact of nanoparticles on the environment.

**CO3** : To create awareness about the toxicity of nanoparticles.

**CO4** : To impart an approach to e-waste and its management.

### ANALYSES OF NANOPARTICLES IN THE ENVIRONMENT

Compositional Analysis - Single Particle Mass Spectrometer - Particle-Induced X-Ray Emission (PIXE) - Surface Area: Product Characterization and Air Monitoring - The Brunauer Emmett Teller (BET) Method. Epiphaniometer - Aerosol Diffusion Charger - Size Distribution-Electrostatic Classifiers- Real-Time Inertial Impactor: Cascade Impactors- Electrical Low Pressure Impactor (ELPI) - Dynamic Light Scattering (DLS) - Workplace Air Monitoring-Condensation Particle Counter (CPC) - Surface Area: Total Exposure-Sampling and Analysis of Waters and Soils for Nanoparticles. (9)

### ENVIRONMENTAL FATE AND TRANSPORT

Nature of Nanomaterials in the Environment - Physical Manifestation of Nanomaterials: Particle Size Distribution and Formation of Mobile Suspensions - Chemical Forces Acting on Nanomaterials - Electrostatic or Coulomb Force-van der Waals Forces - Solvency Force-Implications of Polymorphism - Predicting the Behavior of Nanomaterials in the Environment- Predicting Temporal Reaction Rates: Chain Interactions - Predicting Temporal Reaction Rates: Estimating Particle Affinities - Nanoparticle Affinity and Inter-Particle Force Fields - Coulomb Energy- van der Waals Energy-Prediction of Probability of Product Formation. (9)

### POTENTIAL ECOLOGICAL HAZARDS OF NANOMATERIALS

Underlying Principles of Ecological Exposure, Effects, and Risk Terrestrial vs. Aquatic Ecosystems - Risk and Hazard - Toxicity - Exposure - Factors that can affect the Toxicology of Nanomaterials - Toxicity of Nanomaterials - Exposure to Nanomaterials - Sources and Routes of Exposure - Exposure and Dose - Anticipated Hazards To Terrestrial Ecosystems - Anticipated Hazards to Aquatic Ecosystems - Methodologies for Evaluating Hazards and their Limitations.- Recommendations for Managing the Risks of Future Nanomaterials and their Production. (9)

### E-WASTE MANAGEMENT

WEEE - The Scale of the Problem - Legislative Influences on Electronics Recycling - Producer Responsibility Legislation - The WEEE Directive - The RoHS Directive - Other Examples of Legislation - Treatment Options for WEEE - Material Composition of WEEE-Socio-economic Factors - Logistics of WEEE- WEEE - the International Perspective - European Perspective-Japan - Barriers to Recycling of WEEE - The Recycling Hierarchy and Markets for Recyclate -WEEE Health and Safety Implications. (9)

### INTEGRATED APPROACH TO E-WASTE RECYCLING

Recycling and Recovery Technologies - Sorting/Disassembly-Crushing/Diminution -Separation - Emerging Recycling and Recovery Technologies - Automated Disassembly - Comminution -Separation - Thermal Treatments - Hydrometallurgical Extraction - Dry Capture Technologies - Biotechnological Capture - Sensing Technologies - Design for Recycling and Inverse -Manufacturing - Printed Circuit Boards - Sector-based Eco-design. (9)

**TOTAL : 45**

### REFERENCES

1. S. Kathleen, M. Christopher, L. Lynn. Bergeson, *Nanotechnology and the Environment*, CRC press 2009.
2. R. E. Hester, R. M. Harrison, *Electronic Waste Management*, RSC publishing, 2009.
3. Darcy J. Gentleman, *Nano and the Environment: Boon or Bane?" Environmental Science and Technology*, ACS Publication, Vol. 43, 2009.

# 19MNE14 - DESIGN AND ANALYSIS OF EXPERIMENTS

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : Given a set process data, characterize the process behavior using descriptive statistics.
- CO2** : Identify if the process in control. If not, identify special patterns that may exist.
- CO3** : Design experiments to identify the main effects, interaction effects and their significance.
- CO4** : Student gets well equipped in designing experiment.

### INTRODUCTION

Basic principles, guide lines for designing experiments, basic statistical concepts, inferences about the difference in mean, randomized, pair comparison designs, analysis of variance. (9)

### RANDOMIZED BLOCKS, LATIN SQUARES AND RELATED DESIGNS

Completely randomized, randomized Latin square, Graceo-Latin Square and crossover designs. (9)

### FACTORIAL DESIGNS

Advantage of factorials, description, calculation of direct and interaction effects. 2k factorial designs. Blocking and confounding -principles and use of confounded designs. (9)

### FRACTIONAL FACTORIAL DESIGN

Two three and mixed level fractional designs and applications. (9)

### RESPONSE SURFACE DESIGN

Fitting regression model. Response Surfaces-First and Second order designs. (9)

**TOTAL : 45**

### TEXT BOOK

1. Douglas C. Montgomery, *Design and Analysis of Experiments*, John Wiley and Sons INC., Fifth Edition, 2003.

### REFERENCES

1. W.G. Cochran, G.M. Cox, *Experimental Designs*, Second Edition, John Wiley and Sons, 1957
2. John Lawson, John Erjavee, *Modern Statistics for Engineering and Quality Improvement*, Duxbury, 2001.
3. Stephen R Schmidt and Robert G. Launsby, *Understanding Industrial Designed Experiments*, Air Academy Press, 1992.
4. O.L. Davies, *The Design and Analysis of Experiments*, Longman Group Ltd., 1978.
5. Andre I Khuri, John A Cornel, *Response surfaces - Design and Analysis*, New York Marcel Dekker, 1996.

# 19MNE15 - DIGITAL PROCESS DYNAMICS AND CONTROL

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

**CO1** : To understand the advanced control techniques, ratio, cascade and MPC systems.

**CO2** : Identify methods for various concepts and in industries to control the variables.

**CO3** : To understand the concepts of conversion of analog to digital and vice versa and hardware components of the control system.

### OPEN AND CLOSED SYSTEM

Review of first order and higher order systems, closed and open loop response to step, impulse and sinusoidal inputs. Design of control systems control valve, types - linear, equal percentage and quick opening valve. Block diagram - presentation of system.

(9)

### ADVANCED CONTROLLERS

Advanced control techniques, cascade ratio, feed forward, Adaptive control, Selective control, computing relays, simple alarms, smith predictor, internal model control, theoretical analysis of computer process.

(8)

### MULTIVARIABLE CONTROLLER

Multi loop system- level process, Stability of multi-variable systems, Non-linear systems. Decoupling of control loops and Relative Gain-Array.

(8)

### DIGITAL CONTROLLERS

Digital computer, computer- process interface, computer control loops, new control design problems, Z-transforms, inversion of Z-transforms. Sampling of continuous signals, reconstruction-hold devices, conversion of continuous to discrete-time models.

(12)

### DYNAMIC SYSTEM AND STABILITY

Discrete time response of dynamic systems, discrete time analysis of continuous systems, pulse transfer function, discrete time analysis of closed loop system, stability of discrete -time systems. Digital approximation of classical controllers, effect of samples, tuning and process identification. Zeigler-Nicholas and Cohen-Coon tuning methods, ringing and placement of poles, Design of optimal regulatory control problems.

(8)

**TOTAL : 45**

### TEXT BOOKS

1. Stephanopoulos G., *Chemical Process Control: An Introduction To Theory And Practice, Sixth Edition, Prentice Hall of India Pvt.Ltd, New Delhi, 1998.*
2. Luyben W.K., Luyben M.L., *Essentials of process control, Second Edition, McGraw hill, New York, 1997.*
3. Cougnowr D., Steven Leblanc, *Process Systems Analysis and Control, Third Edition, McGraw Hill, New York, 2008.*

### REFERENCES

1. Carlos A. Smith, Armando B. Corripio, *Principles and Practice of Automative Process control, John Wiley, New York, 2005.*
2. Karl Johan Astrom, Bjorn Witten mark, *Computer controlled systems. Theory and design, Third Edition, Prentice Hall of India Pvt. Ltd., New Delhi, 1996.*

## 19MNE16 - RESEARCH METHODOLOGY

L	T	P	C
3	0	0	3

### ASSESSMENT : THEORY

#### COURSE OUTCOMES

- CO1** : Ability to critically evaluate current research and propose possible alternate directions for further work.
- CO2** : Ability to develop hypothesis and methodology for research.
- CO3** : Identify the influencing factor or determinants of research parameters.
- CO4** : Ability to comprehend and deal with complex research issues in order to communicate their scientific results clearly.

#### DEFINING THE RESEARCH PROBLEM AND DATA COLLECTION METHODS

Research methodology - definition, mathematical tools for analysis, Types of research, exploratory research, conclusive research, modeling research, algorithmic research, Research process- steps. Data collection methods- Primary data - observation method, personal interview, telephonic interview, mail survey, questionnaire design. Secondary data- internal sources of data, external sources of data. (9)

#### MEASUREMENT, SCALING TECHNIQUES AND SAMPLING FUNDAMENTALS

Scales - measurement, Types of scale - Thurstone's Case V scale model, Osgood's Semantic Differential scale, Likert scale, Q-sort scale. Sampling methods- Probability sampling methods - simple random sampling with replacement, simple random sampling without replacement, stratified sampling, cluster sampling. Non-probability sampling method - convenience sampling, judgment sampling, quota sampling. (9)

#### TESTING OF HYPOTHESIS - I

Hypotheses testing - Testing of hypotheses concerning means (one mean and difference between two means -one tailed and two tailed tests), Concerning variance - one tailed Chi-square test. (9)

#### TESTING OF HYPOTHESIS - II

Nonparametric tests- One sample tests - one sample sign test, Kolmogorov- Smirnov test, run test for randomness, Two sample tests - Two sample sign test, Mann- Whitney U test, K-sample test - Kruskal Wallis test (H-Test) (9)

#### ANALYSIS OF DATA, INTERPRETATION AND REPORT WRITING

Introduction to Discriminant analysis, Factor analysis, cluster analysis, multidimensional scaling, conjoint analysis. Report writing- Types of report, guidelines to review report, typing instructions, oral presentation (9)

**TOTAL : 45**

#### TEXT BOOK

1. C.R. Kothari, *Research Methodology Methods and techniques*, New Age Publications, New Delhi, 2009.

#### REFERENCES

1. R. Panneerselvam, *Research Methodology*, Prentice Hall of India, New Delhi, 2004.
2. L.H. Kidder, *Research Methods in Social Relations*, Hall Saunders International, Japan, 1981.
3. A.M. Sedhu, A. Singh, *Research Methodology in social Sciences*, Himalaya Publishing House, Mumbai, Second edition, 2006.

# 19MNE17 - INTELLECTUAL PROPERTY RIGHTS AND INNOVATION

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : *Creating awareness about the essence and importance of Intellectual Property Rights (IPR)*
- CO2** : *Developing skills of Business Enterprises in Nanotechnology and Project Management.*
- CO3** : *Developing skills in protecting Intellectual Property rights for the inventions of Nanotechnology*
- CO4** : *Providing depth knowledge on obtaining Patent, Trade Mark, Copyright, and Design.*
- CO5** : *Enhancing the responsibility to increase the socio-economic prosperity of the country.*

### BACKGROUND

Introduction: the invisible infrastructure of innovation-Intellectual Property Dynamics in Society- The types of Intellectual Property- Patent documents-the construction of the patent, face of the patent, conception, body of the patents - The innovation cycle- The rise of the intellectual property system-Balancing the tension between exclusive rights and the accessible domains. (9)

### BASICS OF MANAGING INTELLECTUAL PROPERTY IN ORGANIZATIONS

The innovation forest: intellectual property rights and how they grow- The ABCDs of intellectual property: flow and infringement of IP rights-the patent system - copyrights- trademarks-trade secrets- The global diversity of innovation communities-The role of the innovation chief. (9)

### NANOTECHNOLOGY POLICY AND REGULATION

Understanding Nanotechnology- the industrial structure giving rise to Nanotechnology- Societal and Ethical Implications- Environmental Regulation - National Security and Export Controls- Federal Funding-Conclusions. (9)

### THE ECONOMIC AND LEGAL FOUNDATIONS

A Brief Digression into Terminology - Understanding Open Source - Credit Unions - Open Source: An Analogy - The Role of Open Source Licenses - Different Types of Open Source Licenses- Law and Code - Intellectual Property and Market Failure - Evaluating the System. (9)

### STRATEGIC MANAGEMENT OF INTELLECTUAL PROPERTY

A menu of strategy options, -Evaluating internal resources and the external environment - Placing a financial value on IP assets - Accessing innovations of others - Protecting and enforcing IP rights- Transferring IP rights -Strategies on a Global Stage-Specific IP strategies for different communities- Global challenges. (9)

**TOTAL : 45**

### REFERENCES

1. *Michael Golin, Driving Innovation-Intellectual Property strategies for a dynamic world", Venable LLP, Washington DC, 2008.*
2. *Van Lindberg, Intellectual Property and Open Source:-A Practical guide to Protecting code O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, 2008.*
3. *John C. Miller, Ruben Serrato, The Handbook of Nanotechnology, Business, Policy, and Intellectual Property Law, John Wiley & Sons, Inc., New Jersey,2005.*
4. *Attorney Richard Stim, Patents, Copyrights, Trademarks,An Intellectual Property desk Reference, 8th Ed., Berkeley, 2006.*

# 19MNOE01 - NANOELECTRONICS AND SENSORS

L	T	P	C
3	0	0	3

## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : To provide an introduction to conventional and novel electronic devices for different applications.
- CO2** : Ability to understand the device architecture for various application.
- CO3** : To describe the classification of sensor based on various parameters.
- CO4** : To develop the idea of processing the physical input signal of a sensor and apply it to a real time application.

### SEMICONDUCTOR NANODEVICES

Single-Electron Devices; Nano scale MOSFET - Resonant Tunneling Transistor - Single-Electron Transistors; Single-Electron Dynamics; Nanorobotics and Nanomanipulation; Mechanical Molecular Nanodevices; Nanocomputers: Theoretical Models; Optical Fibers for Nanodevices; Photochemical Molecular Devices; DNA-Based Nanodevices; Gas-Based Nanodevices; Micro and Nanomechanics. (9)

### ELECTRONIC AND PHOTONIC MOLECULAR MATERIALS

Preparation -Electroluminescent Organic materials - Laser Diodes - Quantum well lasers:- Quantum cascade lasers- Cascade surface-emitting photonic crystal laser- Quantum dot lasers- Quantum wire lasers:- White LEDs - LEDs based on nanowires - LEDs based on nanotubes- LEDs based on nanorods High Efficiency Materials for OLEDs- High Efficiency Materials for OLEDs - Quantum well infrared photo detectors. (9)

### THERMAL SENSORS

Thermal energy sensors -temperature sensors, heat sensors- Electromagnetic sensors- electrical resistance sensors, electrical current sensors, electrical voltage sensors, electrical power sensors, magnetism sensors - Mechanical sensors -pressure sensors, gas and liquid flow sensors, position sensors - Chemical sensors - Optical and radiation sensors. (9)

### GAS SENSOR MATERIALS

Criteria for the choice of materials, Experimental aspects - materials, properties, measurement of gas sensing property, sensitivity; Discussion of sensors for various gases, Gas sensors based on semiconductor devices. (9)

### BIOSENSORS

Principles- DNA based biosensors - Protein based biosensors - materials for biosensor applications- fabrication of biosensors- future potential. (9)

**TOTAL : 45**

### REFERENCES

1. W. Ranier, *Nano Electronics and Information Technology*, Wiley, 2003.
2. K.E. Drexler, *Nano systems*, Wiley, 1992.
3. M.C. Pettey, *Introduction to Molecular Electronics*, 1995.

## 19MNOE02 - SAFETY ENGINEERING

L	T	P	C
3	0	0	3

### ASSESSMENT : THEORY

#### COURSE OUTCOMES

- CO1** : Gives standard limitation to dispose waste to prevent health and environmental effect and also quantifying risk analysis
- CO2** : To explore tools and techniques required for risk reduction.
- CO3** : To identify the sources causing hazard and gives the control methods, storage and handling of hazardous chemicals.
- CO4** : To apply hazard identification and assessment techniques for safe system design.

#### INTRODUCTION

Safety Total definition Hazard identification, General hazards of plant operation Toxic hazards, Fire and Explosions - Hazards Transport of Chemicals with safety Unforeseen deviations Emergency management, Planning for safety, Selecting a basics of safety Preventive and protective measures, Safety based on emergency, Relief systems, Safety based on containment Operational safety procedural instructions Sla-Routine checks, Process and product changes, Safety Checks, Checklist for safety, Leaks and detection. (9)

#### HAZARDS AND EFFECTS

Hazards of plant operation, Toxic Hazards, Fire and explosion hazards, Reaction hazards, Literature calculations and Explosions Screening, Normal reaction, Gas evolution, Characterizing Runaways, Control and Mitigation of Gas emanations, Absorption with Chemical reaction, Health and environ effects. (7)

#### SAFETY DISPOSAL METHODS

Special Problem of Developing countries, Safety gadgets, Dispersions, Degree of hazards, Disposals, Hierarchy of options, I.C.A. Application, Nil Hazards and Alternate methods, Threshold limits, Laws of safety, Accident Reporting. (6)

#### WASTE MANAGEMENT AND ECONOMICS

Storage, Central handling safety, Unintentional spills, Runoff Emits, Containment economics, Waste disposal and environ projection, Incineration, Alternatives. (8)

#### RISK ANALYSIS

Risk Analysis, Evaluation, Mitigation, Hazop, Hazan, Definition, Probability, Quantification-Risk, Engineering, Clean technology, Initiatives, Standards, Emergency Handling, Accident Investigation, Legislation, Nil Risk Quantification methods, Case histories of accidents, Examples of hazards assessment, Examples of use of Hazan, Explosion hazards in Batch units, Technical process, Documentation for Hazardous Chemicals, Format and methods. (15)

**TOTAL : 45**

#### TEXT BOOKS

1. G.L. Wells, R.M.C. Seagrave, *Flow sheeting for safety*, Indian Institute of Chemical Engineering, London UK, 1977.
2. Trevor Kletz Butterworth, *Learning from accidents*, London, 1988.
3. John Barton, Richard Rogers, *Chemical Reaction Hazards - A guide to safety*, Institution of Chemical Engineering London, 1997.

#### REFERENCES

1. A.K. Rohatgi, *Safety Handling of Hazardous Chemicals Enterprises*, Bombay, 1986.
2. S.K. Shukla., *Envirohazards and Techno Legal aspects*, Shashi Publications, Jaipur India, 1993.

# 19MNOE03 - SOCIETAL IMPLICATIONS OF NANOTECHNOLOGY

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## ASSESSMENT : THEORY

### COURSE OUTCOMES

- CO1** : Ability to understand the impact of nanotechnology in the society.
- CO2** : Able to know about the ethics to be followed in nanotechnological research.
- CO3** : Able to connect the various disciplines of nano research.
- CO4** : Ability to develop knowledge on commercialization of nano products.

### ECONOMIC IMPACT OF NANOTECHNOLOGY

Socio-Economic Impact of Nanoscale Science - Managing the Nanotechnology Revolution: Consider the Malcolm Baldrige National Quality Criteria - The Emerging Nano Economy: Key Drivers, Challenges, and Opportunities - Transcending Moore's Law with Molecular Electronics and Nanotechnology - Semiconductor Scaling as a Model for Nanotechnology Commercialization - Sustaining the Impact of Nanotechnology on Productivity, Sustainability and Equity. (9)

### SOCIAL SCENARIOS

Navigating Nanotechnology Through Society - Nanotechnology, Surveillance, and Society: Methodological Issues and Innovations for Social Research - Nanotechnology: Societal Implications: Individual Perspectives - Nanotechnology and Social Trends - Five Nanotech Social Scenarios-Technological Revolutions and the Limits of Ethics in an Age of Commercialization - Vision, Innovation, and Policy. (9)

### CONVERGING TECHNOLOGY AND GOVERNANCE

Nanotechnology's Implications for the Quality of Life - Management of Innovation for Convergent Technologies - The "Integration/ Penetration Model:" - The Use of Analogies for Interdisciplinary Research in the Convergence of Nano-, Bio-, and Information Technology - Converging Technologies: Innovation, Legal Risks, and Society .Governance- Problems of Governance of Nanotechnology -Institutional Impacts of Government Science Initiatives - Nanotechnology for National Security. (9)

### ETHICS AND LAW

Ethics and Law - Ethical Issues in Nanoscience and Nanotechnology: Reflections and Suggestions - Ethics and Nano: A Survey - Law in a New Frontier - An Exploration of Patent Matters Associated with Nanotechnology - The Ethics of Ethics - Negotiations over Quality of Life in the Nanotechnology Initiative. (9)

### PUBLIC PERCEPTION AND PARTICIPATION

Public Interaction Research - Communicating Nanotechnological Risks - A Proposal to Advance Understanding of Nanotechnology's Social Impacts - Nanotechnology in the Media: A Preliminary Analysis - Public Engagement with Nanoscale Science and Engineering - Nanotechnology: Moving Beyond Risk - Communication Streams and Nanotechnology: The (Re)Interpretation of a New Technology - Nanotechnology:Societal Implications - Individual Perspectives. (9)

**TOTAL : 45**

### REFERENCES

1. Mihail C. Roco, William Sims Bainbridge, *Nanotechnology: Societal Implications-IIIIndividual Perspectives*, Springer,2007.
2. Geoffrey Hunt and Michael D. Mehta, *Nanotechnology: Risk, Ethics and Law*, Earthscan/James & James publication, 2006.
3. Jurgen Schulte, *Nanotechnology: Global Strategies, Industry Trends and Applications*, John Wiley & Sons Ltd.,2005.
4. Mark. R. Weisner and Jean-Yves Bottero, *Environmental Nanotechnology applications and impact of nanomaterial*, The McGraw-Hill Companies, 2007.