BIJU PATNAIK UNIVERSITY OF TECHNOLOGY, ORISSA

M.TECH IN POLYMER NANOTECHNOLOGY

First Semester

Course Code	Course Title	L	T	P	Cr
	THEORY				
1.	Polymer Chemistry & Physics	3	1	0	4
2.	Introduction to Nanotechnology	3	1	0	4
3.	Polymeric Nanomaterials Processing Techniques & their Applications	3	1	0	4
4.	Elective I • Applied Mathematics and Simulation Techniques • Thermodynamics and optimization of nanomaterials	3	1	0	3
5.	Elective II • Nanotubes & related Nanostructures • Nanocomposites & Nanofillers in Bulk Polymers	3	1	0	3
	PRACTICALS				
6.	Polymer Engineering laboratory	0	0	3	2
7.	Nanomaterial Testing Lab	0	0	3	2
9.	Pre-thesis work and Seminar I	0	0	3	2
	TOTAL CREDITS				**24**

Second Semester

Course Code	Course Title	L	T	P	Cr
	THEORY				
1.	Nanofabrication Technology	3	1	0	4
2.	Characterization of Polymeric Nanomaterials	3	1	0	4
3.	Elective III • Mechanics of Finite Size Elements • Technology, innovation and quality management	3	1	0	3
4.	Elective IV • Micro/Nanofluidics - Design & Modelling • Nanopolymers in Medicine	3	1	0	3
5.	Elective V • Polymer based Optical, Electronic & Magnetic Materials • Nanomaterials for Energy & Environment	3	1	0	3
	PRACTICALS				
6.	Nanoscience and Technology Lab	0	0	3	2
8.	Polymer Processing and Advanced Computer Aided Engineering Techniques	0	0	3	2
9.	Pre-thesis work and Seminar II	0	0	3	2
10.	Comprehensive Viva-voce - I	0	0	3	2
	TOTAL CREDITS				**25**

Third Semester

Course Code	Course Title	L	T	P	Cr
11	Thesis part I	-	-	-	14
12	Open Elective • Biodegradable plastics and environmental engineering • Recycling of plastics & waste management	3	1	0	3
	TOTAL CREDITS				**17**

Fourth Semester

Course Code	Course Title	L	T	P	Cr
13	Thesis part II	-	-	-	20
14	Seminar				2
15	Comprehensive Viva-voce II				2
	TOTAL CREDITS				**24**

Total credits: 90 (Break-up as per BPUT guidelines)

Subject Items	Credits
Professional Core	20
Professional Elective	18
Sessionals / Laboratory	8
Project	34
Seminar	6
Comprehensive Viva-Voce	4
TOTAL	**90**

FIRST SEMESTER

1. POLYMER CHEMISTRY & PHYSICS (3-1-0) 4 Cr

Module I (10 hours)

Functionality, bi-functional and poly functional systems, classification and nomenclature of polymers, branching and crosslinking, glassy and crystalline states, thermodynamics of crystallization, kinetics of melting, crystal morphology, free volume, time - temp equivalency, distribution of molecular size, stoichiometric imbalance.

Module II (8 hours)

Molecular weight, molecular weight distribution, polydispersity, degree of polymerization, molecular weight determination, viscosity of polymers solutions, molecular weight dependence of viscosity and size of polymer molecules.

Module III (12 hours)

Types of polymerization, polymerization techniques, copolymers and stereo-regular polymers, reactivity ratios, copolymer composition and microstructure, Price - Alfrey equation, Flory - Huggins theory, polymer fractionation, Mark - Hownick equation, diffusion coefficient and friction factor.

Module IV (10 hours)

Elastic deformation, shear modulus and compliances, Maxwell model, Voigt model, dynamic viscoelasticity, molecular theory for viscoelasticity - Rouse model, Coefficient of viscosity, viscosity measurement, Power Law for pseudoplastic liquids, effect of shearing forces, segmental friction factor, Bueche theory, Reptation model.

Text Books

1. Gedde Ulf. W. Polymer Physics, Chapman & Hall London (1995)
2. Rodriguez, Ferdinand, Principles of Polymer Systems Mc. Craw – Hill, International Book Co. International Student Edn. 1985.

3. Cowie; JMG Polymers: Chemistry & Physics of Modern Materials, Nelson Thornes ltd. Chelterham, 2001
4. Hiemenz; Paul C. Polymer Chemistry- The Basic Concepts; Marcell & Deckker, Inc. New York (1984)

Reference Books

1. Principles of Polymer Chemistry, Paul J Flory
2. JL Fried, Polymer Science & Technology

2. INTRODUCTION TO NANOTECHNOLOGY (3-1-0) 4 Cr

Module I (10 hours)

Importance and emergence of nanotechnology, challenges, current and future research. Size dependence of properties, crystal structure, energy bands, insulators, semiconductors and conductors, gaps of semiconductors, Fermi surfaces, localized particles.

Module II (12 hours)

Laws of thermodynamics applied to nanoscale systems; activity and the equilibrium constant; solutions; phase relations; heterogeneous equilibria; free-energy-composition diagrams and their relation to phase transitions; phase diagrams.

Module III (12 hours)

Polymer based nanocrystals, supramolecular structures, polypeptide nanowire, and protein nanoparticles. Microelectromechanical systems (MEMS) Nanoelectromechanical systems (NEMS): fabrication and application, molecular and supramolecular switches. Optical and vibrational spectroscopy, luminescence, quantum wells, wires and dots.

Module IV (10 hours)

Metal nanoclusters, semiconductor nanoparticles, rare gas and molecular clusters: synthesis and properties, carbon molecules and clusters, applications of carbon nanotubes. Nanostructured materials: solid disordered nanostructures, natural nanocrystals, zeolites, photonic crystals, nanostructured multilayers.

Text Books

1. Introduction to Nanotechnology - Charles P Poole Jr, Frank J Owens
2. Mark Ratner, Daniel Ratner. - Upper Saddle River, Nanotechnology: A Gentle Introduction to the next Big Idea, c2003, Prentice hall.
3. Callister, William D. Jr., Fundamentals of Materials Science and Engineering: An Integrated Approach 2nd Ed., John Wiley and Sons, 2003
4. Nanotechnology Understanding Small Systems, Rogers Pennathur Adams, CRC Press, Taylor & Francis Group.

Reference Books

1. Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2005
2. Edward l Wolf. - Weinheim, Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, c2004, Wiley
3. S. N. Sahu, R. K. Choudhury, and P. Jena, Nano-scale Materials: From Science to Technology, Nova Science Publishers, 2006.
4. Yannick Champion, Hans-Jörg Fecht, Nano-Architectured and Nanostructured Materials: Fabrication, Control and Properties, Wiley-VCH,2005.
5. Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2005

3. POLYMERIC NANOMATERIALS PROCESSING TECHNIQUES & THEIR APPLICATIONS (3-1-0) 4 Cr

Module I (12 hours)

Processing of Nanoparticles - Binding mechanisms in Nanoparticles, Dispersion of Nanoparticles, Stabilization of Nanoparticles. Processing and fabrication of polymer nanocomposites - Melt blending, Solvent casting, In-situ polymerization, Solution polymerization, Template synthesis, High shear mixing.

Module II (10 hours)

Homogenoeous/heterogeneous nucleation, plasma promoted nucleation, Cold Plasma Methods, Atomic layer deposition fundamentals, Laser ablation, Vapour – liquid – solid growth, particle precipitation aided CVD.

Module III (12 hours)

Processes for producing ultrafine powders - Mechanical grinding; Wet Chemical Synthesis of nanomaterials- sol-gel process, Liquid solid reactions. Gas Phase synthesis of nanomaterials- Furnace, Flame assisted ultrasonic spray pyrolysis; Gas Condensation Processing (GPC), Chemical Vapour Condensation (CVC).

Module IV (12 hours)

Polymer nanocomposites with structural, gas barrier and flame retardant properties, carbon fiber reinforced polymer composites, elastomer and thermoplastic elastomer nanocomposites for propulsion systems, water borne fire-retardant Nanocomposites, hybrid composites for cosmetics, protective and decorative coatings.

Text Books

1. Chung; Deborah D. L., Composite Materials: Science and Applications, Spinger International Edition, Springer-Verlag, London (2004)-Indian Edition 2006
2. Ishida; Hatsud, Characterization of Composite Materials, Butterworth Heinemann, Boston (1994).
3. Fundamentals of Fiber Reinforced Composite Materials, AR Bunsell, J Renard, Institute of Physics, Series in Materials Science & Engg.
4. Introduction to Nanotechnology - Charles P Poole Jr, Frank J Owens
5. Chu; Paul K. and Liu; Xuanyong (Eds.), Biomaterials Fabrication and Processing Handbook, CRC Press, Boca Raton (2008)

Reference Books

1. Carl C. Koch, Nano-structured materials: Processing, Properties and Potential Applications, Noyes Publishers & William Andrews Publishers, New York 2002
2. Guozhong Cao, Nanostructures and Nanomaterials, Imperial College Press, London 2004

3. Mechanical Metallurgy - George E Dieter
4. Mechanical Behaviour of Materials - Thomas H Courtany
5. B. T. Astrom, Manufacturing of Polymer Composites, Chapman and Hall, London 1995
6. T. G. Gutowski, Advanced Composites Manufacturing, John Wiley and Sons, New York 1997
7. T J Pinnavaia, G M Beall Hardcover, Polymer-Clay Nanocomposites, December 2000, Wiley

4. ELECTIVE I (3-1-0) 3 Cr

(a) APPLIED MATHEMATICS & SIMULATION TECHNIQUES

Module I (10 hours)

Finite Difference Methods: Finite difference approximations. Two- point boundary value problems for ODE. Advection equations and the method of lines. The heat equation and semi-implicit methods. Linear convergence/stability analysis. Finite element analysis: Variational formulations for two-point boundary value problems. Construction of elements and basic convergence analysis.

Module II (10 hours)

Integral Equation Methods: Green's function, layer and volume potentials. Numerical solution of two-point boundary value ODE problems and two dimensional Poisson Equations. Eigen values and Single Value Decomposition: Elementary concepts and a discussion of available numerical routines. Applications of Single Value Decomposition, including solution of rank deficient least squares problems, data/image compression.

Module III (10 hours)

Spectral Methods: Fourier analysis and orthogonal polynomials. Numerical solution techniques for ODE two-point boundary value problems using Fourier series or Chebyshev polynomials. Basic iterative methods including Jacobi's method, Gauss-Seidel, and SOR. Multigrid method for one and two dimensional Poisson's equation. Krylov subspace based methods including Conjugate Gradient (CG) and GMRES.

Module IV (10 hours)

Monte - Carlo Methods: Pseudo random number generators, including the mapping methods, Box-Muller method, and rejection methods, Monte Carlo integration and variance reduction, simulation techniques for Markov Chains, Accurate time stepping methods for stochastic differential equations, Modes of stochastic convergence, The Euler - Maruyama method, Convergence modes of method, The Milstein method.

References

1. Lay, D. C., Linear Algebra and its Applications, Addison Wesley, 2003.
2. Florey, F. G., Elementary Linear Algebra with Application, Prentice Hall, 1979.
3. Hoffman, K. and Kunze, R., Linear Algebra, Prentice Hall of India, 1971.
4. Bell, W. W., Special Functions for Scientists and Engineers, Dover Publications, 2004.
5. Golub, Gene, “Matrix computations”.
6. Briggs, William, “A multigrid tutorial”.
7. Atkinson, Kendall, “An Introduction to Numerical Analysis”.

(b) THERMODYNAMICS AND OPTIMIZATION OF NANOMATERIALS

Module I (10 hours)

Elementary Linear Programming: Systems of linear equations & inequalities –Advanced Linear Programming: Sensitivity analysis- Dynamic Programming and Game Theory: Nature of Dynamic Programming problem – Bellmann’s optimality principle. Relation between theory of games and linear programming.

Module II (8 hours)

Network Path Models: Tree NetworksShortest path problems – Solution methods – Dijkstra’s Method – Floyd’s Algorithm – Network flow Algorithms – Maximal flow algorithm – The method of Ford and Fulkerson.

Module III (10 hours)

Hess' Law- Entropy and Criterion for Equilibrium – Statistical interpretation of entropy – Boltzmann equation. Auxiliary Functions – Maxwell's Equations – Gibbs – Helmholtz Equation – First, second, and third laws of thermodynamics as applied to nanoscale systems- Phase Equilibrium– Thermodynamics and kinetics of phase transformations.

Module IV (10 hours)

Homogeneous nucleation- Heterogeneous nucleation - Growth and overall transformation rate-Physical phenomena of small systems - nano-crystals, macromolecules, thermodynamics and physical properties of long chain molecules and molecular structures.

References:

1. Bazarra M. S. Jarvis J. J, H. D. Sherali-Linear programming and Network flows – John Wiley, II edition, 1990.
2. Bazarra M. S. Sherali. H. D, & Shetty. C. M. Nonlinear Programming Theory and Algorithms – John Wiley, II edition, 1993.
3. Hadley. G. Linear Programming , Narosa Publishing House, 1990.
4. Hillier F. S & Liebermann G. T. Introduction to OR. Mc. Grand Hill, VII edition,
5. David V. Ragone, Thermodynamics of Materials, Volume I, J. W. Wiley 1995.
6. Thermodynamics in Materials Science, By Robert T. DeHoff, McGraw-Hill, 1993.
7. Stoichiometry and Thermodynamic Computations in Metallurgical Processes, Y.K. Rao, Cambridge University Press, 1985.
8. Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2005

5. ELECTIVE I I (3-1-0) 3 Cr

(a) NANOTUBES & RELATED NANOSTRUCTURES

Module I (10 hours)

Classification of nanostructures, nanoscale architecture, fundamental structure, chemistry, property relationships in nanomaterials and nanomaterial systems, Characteristic scale for quantum phenomena, nanoparticles.

Module II (10 hours)

Carbon nanotubes: structure, single and multi walled carbon nanotubes, symmetry of single walled carbon nanotubes, symmetry based quantum numbers, phonon symmetries in CNTs. Synthesis and purification of carbon nanotubes, structure-property relationships, physical properties, Chemistry & Biology of Nanotubes, Filled & Heterogeneous Nanotubes

Module III (12 hours)

Nature of carbon bond, new carbon structure, discovery of C_{60}, C_{80} and C_{240} nanostructures, alkali doped C_{60}, superconductivity in C_{60}, Fullerene structure and bonding, other buckyballs. Electronic, transport, optical, thermal, vibration and mechanical properties of nanotubes, application of nanomaterials.

Module IV (10 hours)

Zone-folding approximation, electronic density of states, nanotubes bundles. Quantum wells, quantum dots, quantum wires, nano-clusters, clusters of rare gases, clusters of alkali metals, The Jellium model. Field emission and shielding, computer fuel cells, chemical sensors, catalysis.

Text Books

1. Carbon Nanotube Science: Synthesis, Properties & Applications, Peter JF Harris, University of Reading UK, Cambridge University Press
2. Introduction to Nanotechnology - Charles P Poole Jr, Frank J Owens
3. Jorio A., Dresselhaus G., and Dresselhaus M.S. (Eds.), Carbon Nanotubes – Advanced Topics in the Synthesis, Structure, Properties and Applications, Springer Verlag, New York, 2008.

Reference Books

1. Stephanie Reich, Christian Thomsen, Janina Maultzsch, Carbon Nanotubes: Basic Concepts and Physical Properties, February 2004, Wiley.
2. Michael J. O'Connell, Carbon Nanotubes: Properties and Applications, CRC; 1 edition, 2006.
3. Karl M Kadish, Rodney S Ruoff, Fullerenes: Chemistry, Physics and Technology, July 2000, Wiley.

4. Paul Harrison, Quantum wells, Wires & Dots: Theoretical & Computational Physics of Semiconductors Nano-stuructures.
5. Introduction to Nanoscale Science and Technology (Nanostructure Science and Technology) -Massimiliano Di Ventra

(b) NANOCOMPOSITES & NANOFILLERS IN BULK POLYMERS

Module I (10 hours)

Introduction, historical perspective, composite materials, geometric morphology, advanced matrix, fibers and interfaces. Unidirectional composites, Analysis of laminated composites through computers, hygrothermal stresses, fatigue failure mechanisms, experimental characterization of composites.

Module II (10 hours)

Synthesis methods of Nanocomposites - self Assembly or Bio-Mimetic processes, Film; Evaluation of strength and failure criteria of composites.

Module III (12 hours)

Types of fillers / reinforcing agents - Montmorrillonite nanoclays, polyhedral oligomeric silsequioxane (POSS), vapour - grown fibers, carbon nanofibers, carbon nanotubes, inorganic nanomaterials - silica, alumina, titanium dioxide.

Module IV (10 hours)

Special nanostructured materials - Fullerenes - Magnetism and tunnelling, Fullerenes films other applications, carbon onions, Porous silicon - Preparation methods, Electro spinning & CNT composites.

Text Books

1. Introduction to Nanotechnology - Charles P Poole Jr, Frank J Owens
2. Carbon Nanotube Science: Synthesis, Properties & Applications, Peter JF Harris, University of Reading UK, Cambridge University Press
3. Chung; Deborah D. L., Composite Materials: Science and Applications, Spinger International Edition, Springer-Verlag, London (2004)-Indian Edition 2006

4. Ishida; Hatsud, Characterization of Composite Materials, Butterworth Heinemann, Boston (1994).
5. Hari Singh Nalwa, Polymeric Nanostructure & their Applications, American Scientific Publishers, 2006

Reference Books

1. Pulickel M Ajayan, Linda S Schadler, Paul V Braun Hardcover, Nanocomposte Science & Technology, September 2003, Wiley
2. Jean-Francois Gerard, I Meisel, C S Kniep, S Spiegal, K Grieve, Fillers & Filled Polymers, July 2001, Wiley
3. Gero Decher, Joseph B Schelnoff Hardcover, Multilayer Thin Films: Sequential Assembly of Nanocomposite Materials, January 2003, Wiley
4. Joseph H Koo, Polymer Nanocomposites
5. B.D. Agarwal and L.J. Broutman, "Analysis and Performance of Fibre Composites", John Wiley & Sons Inc.
6. Stephen W Tsai, H. Thomas Hahn, "Introduction to Composite Materials", Technomic Publishing Company
7. R. M. Jones, "Mechanics of Composite Materials", McGraw-Hill.
8. F L Mathews & R D Rawlings, Composite Materials: Engineering & Science, Wood head Publishing

PRACTICALS

6. POLYMER ENGINEERING LABORATORY (0-0-3) 2 Cr

1. Surface modification of nanoparticles and nanoclays: Red Mud, Fly ash, TiO_2 , Montmorillonite, Bentone etc.
2. Melt mixing of nanoparticles in polymer matrix using batch mixer & Process optimization
3. Specimen preparation of polymer nanocomposites by using injection molding.
4. Synthesis, melt rheology, crystal structure and mechanical properties of polymer Clay-polymer nanocomposites & nanofillers.
5. Thermodynamics of crystallization, crystallization kinetics of polymers nanocomposites.
6. Molecular weight characterization by gel permeation chromatography (GPC)

7. NANOMATERIAL TESTING LAB (0-0-3) 2 Cr

1. Measurement of mechanical properties of polymer nanocomposites
2. Studies on thermal properties of nano materials through DSC & TGA analysis
3. Observation of nanostructures of nanoparticles & nanocomposites using XRD, AFM, TEM, SEM, FTIR
4. Measurement of viscoelastic properties of nanocomposites by using DMA
5. Measurement of optical, magnetic and electrical properties of nanomaterials & polymer nanocomposites

8. PRE-THESIS WORK AND SEMINAR I (0-0-3) 2 Cr

The student is required to study on an advanced topic relevant to the field. He/she will be examined through an oral presentation based on the study carried out in the first semester.

SECOND SEMESTER

1. NANOFABRICATION TECHNOLOGY (3-1-0) 4 Cr

Module I (9 hours)

Physical Methods: Inert gas condensation, Arc discharge, RF-plasma, Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy, Chemical vapour deposition method and other variants, Electrodeposition.

Module II (13 hours)

Chemical Methods: Metal nanocrystals by reduction, Solvothermal synthesis, Photochemical synthesis, Electrochemical synthesis, Nanocrystals of semiconductors and other materials by arrested precipitation, Thermolysis routes, Sonochemical routes, Liquid-liquid interface, Hybrid methods, Solvated metal atom dispersion, Post-synthetic size-selective processing. Sol- gel, Micelles and microemulsions, Cluster compounds.

Module III (12 hours)

Biological Methods: Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Synthesis process and application, Role of plants in nanoparticle synthesis.

Module IV (10 hours)

Lithographic Techniques: AFM based nanolithography and nanomanipulation, E-beam lithography and SEM based nanolithography and nanomanipulation, Ion beam lithography, oxidation and metallization. Deep UV lithography, X-ray based lithography.

Text Books

1. Hari Singh Nalwa - Encyclopedia of Nanotechnology.
2. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens
3. Processing & properties of structural nanomaterials by Leon L. Shaw (editor)

Reference Books

1. Microfabrication and Nanomanufacturing- Mark James Jackson
2. Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor
3. Nanomaterials Handbook- Yury Gogotsi
4. Springer Handbook of Nanotechnology - Bharat Bhusan
5. Chemistry of nanomaterials: Synthesis, properties and applications by CNR Rao et.al.
6. Synthesis of Nanostructured Materials –Cao
7. Handbook of Nanoscience, Engineering- Goddard et al

2. CHARACTERIZATION OF POLYMERIC NANOMATERIALS (3-1-0) 4 Cr

Module I (10 hours)

Compositional surface analysis: Ultraviolet (UV) and X-ray photoelectron spectroscopy (XPS), Secondary ion mass spectrometry (SIMS)

Module II (10 hours)

Microscopies: Optical microscopy, fluorescence & confocal microscopy, Cathodoluminescence (CL) and photoluminescence (PL), TEM, SEM

Module III (10 hours)

Probe techniques: Atomic force microscopy (AFM), scanning tunnelling microscopy (STM), scanning nearfield optical microscopy (SNOM), deep level transient spectroscopy (DLTS)

Module IV (10 hours)

Kelvin-probe measurements, Nanoscale current-voltage (I-V), capacitance-voltage (C-V) relationships, thermal & thermo-mechanical analysis (DSC, TGA, DMA)

Text Books

1. Turi; Edith A. (Ed.), Thermal Characterization of Polymeric Materials, Academic Press Inc., New York (1981).
2. Sawyer; Linda C. and Grubb; David T., Polymer Microscopy, Chapman and Hall, London (1987).

3. Mitcheli Jr.; John, Applied Polymer Analysis and Characterization-Recent Development in Techniques, Instrumentation, Problem Solving, Hanser Publishers, Munich (19--).
4. Ishida; Hatsud, Characterization of Composite Materials, Butterworth Heinemann, Boston (1994).
5. Haines; Peter J., Thermal Method of Analysis: Principles, Applications and Problems, 3rd Edition, Blackie Academic and Professional, London (1995).

Reference Books

1. Nanostructures & Nano Materials : Ghuzang Cao
2. Hand Book of Nanophase: Zhong Lin Wang (Springer) & Nanomaterials (Vol. I&II)
3. Microstructural Characterization of Materials - David Brandon and Wayne Kaplan, John Wiley and Sons, New York, NY, 1999.
4. Elements of X-ray Diffraction – BD Cullity and SR Stock, Prentice Hall, New Jersey, 2001.
5. Scanning Electron Microscopy and X-Ray Microanalysis - Joseph I Goldstein, 3rd ed., Dale E. Newbury Academic / Plenum Publishers, New York, 2003.
6. Transmission Electron Microscopy - David B Williams and Barry Carter, Plenum Press, NY. London 1996 (or a newer edition).
7. Principles of Instrumental Analysis - Douglas A Skoog, F. James Holler and Timothy A. Nieman, 4th Edition ©1998.

3. ELECTIVE III (3-1-0) 3 Cr

(a) MECHANICS OF FINITE SIZE ELEMENTS

Module I (10 hours)

Introduction to Finite Element Method: Engineering Analysis, History, Advantages, Classification, Basic steps, Convergence criteria, Role of finite element analysis in computer-aided design., Mathematical Preliminaries, Differential equations formulations, Variational formulations, weighted residual methods.

Module II (12 hours)

One-Dimensional Elements - Analysis of Bars and Trusses: Basic Equations and Potential Energy Functional, 1-0 Bar Element, Admissible displacement function, Strain matrix, Stress recovery, Element equations, Stiffness matrix, Consistent nodal force vector: Body force, Initial strain, Assembly Procedure, Boundary and Constraint Conditions, Single point constraint, Multi-point constraint, 2-D Bar Element, Shape functions for Higher Order Elements

Module III (12 hours)

Two-Dimensional Elements - Analysis of Plane Elasticity Problems: Three-Noded Triangular Element (TRIA 3), Four-Noded Quadrilateral Element (QUAD 4), Shape functions for Higher Order Elements (TRIA 6, QUAD 8), Axi-symmetric Solid Elements-Analysis of Bodies of Revolution under axi-symmetric loading: Axisymmetric Triangular and Quadrilateral Ring Elements. Shape functions for Higher Order Elements

Module IV (12 hours)

Three-Dimensional Elements - Applications to Solid Mechanics Problems: Basic Equations and Potential Energy Functional, Four-Noded Tetrahedral Element (TET 4), Eight-Noded Hexahedral Element (HEXA 8), Tetrahedral elements, Hexahedral elements: Serendipity family, Hexahedral elements: Lagrange family. Shape functions for Higher Order Elements

References:

1. Chandrupatla T. R.,“Finite Elements in engineering”- 2nd Edition, PHI, 2007.
2. Lakshminarayana H. V.,“Finite Elements Analysis”– Procedures in Engineering, Universities Press, 2004
3. Rao S. S. “Finite Elements Method in Engineering”- 4th Edition, Elsevier, 2006.
4. P.Seshu, “Textbook of Finite Element Analysis” -PHI, 2004.
5. J.N.Reddy, “Finite Element Method”- McGraw -Hill International Edition.
6. Bathe K. J. “Finite Elements Procedures”- PHI.
7. Cook R. D., et al., “Concepts and Application of Finite Elements Analysis”- 4th Edition, Wiley & Sons, 2003.

(b) TECHNOLOGY, INNOVATION AND QUALITY MANAGEMENT

Module I (8 hours)

Understanding Management of Technology, innovation technology evaluation, Diffusion. Technology and competition, Integration of strategic planning and technology planning.

Module II (10 hours)

Technology Strategy: Technology intelligence – collaborative mode, Appropriation of technology –Technology evaluation and financing – changing role of R & D, Management of manufacturing technology – corporate cultures – technology audits.

Module III (10 hours)

Introduction to quality – basic concepts, definition, quality of design and conformance, quality circle, ISO 9000 & their documentation. Data collection and presentation – SQC techniques & their applications, presentation of data, frequency distributions and pie diagram.

Module IV (12 hours)

Measures of central tendency & dispersion – calculation of mean, median, mode, standard deviation & variance, concept of distribution, introduction to tests to simple hypothecs. Inspection, sampling & correlation analysis.

References:

1. Babcock D.L. “Managing Engineering Technology” Prentice Hall.
2. Burgelman et.al “Strategic Management of Technology and Innovation” Tata McGraw Hill (2001).
3. Cleland and Bursic “Strategic Technology management” Amacom, Newyork.
4. Narayanan U.K. “Managing Technology and Innovation for competitive Advantage” Pearson Education, Asia 2001.
5. Betz F “Managing Technology – competing Through New Ventures, Innovation and Corporate Research.” Prentice Hall.
6. B. L Agarwal, Basic Statistics, Wiley Eastern Limited, II Chapter
7. Suddhendu Biswas, Statistics of Quality Control, Wiley Eastern Limited, 2008

8. Juran & Geyna, Modern Methods for Quality Control and Improvement, John Wiley & Sons 1986

4. ELECTIVE IV (3-1-0) 3 Cr

(a) MICRO/NANOFLUIDICS - DESIGN & MODELLING

Module I (8 hours)

Physics of fluids at the micrometer and nanometer scale, laminar flow, fabrication of microfluidics and nanofluidic devices, applications of nanofluidics for bionanotechnology.

Module II (12 hours)

Micro/nanofluidic computing, Micro-fluidic system assembly. Fundamental aspects of fluid mechanics, scaling laws, flow transport at small length scales. Capillary-driven, pressure-driven, and electro-kinetic based microfluidics, multi-phase flow, droplet-based microfluidics and complex fluids flow, micro-mixing and pumping systems and cell based microfluidics.

Module III (10 hours)

Nanofluidics and surfaces: liquid structure near solid-liquid interfaces: simple liquids; layering electrolytes: Poisson-Boltzmann equation; Debye Hückel approx., nanofluidic transistors, nanofluidic memory.

Module IV (12 hours)

Hydrodynamics at small scales (laminar flow, slip versus no-slip, mixing), electro kinetic effects, solid-liquid interfaces (interactions, adsorption/desorption), 3-phase systems (capillary forces, wetting, superhydrophobicity), electrokinetic effects (electroosmotic pumping, electroviscous effect), electrophoresis and separation techniques, colloids, surface reconstruction, dangling bonds and surface states.

Text Books

1. Nanotechnology Understanding Small Systems, Rogers Pennathur Adams, CRC Press, Taylor & Francis Group.

2. Fundamentals and Applications of Microfluidics by Nam-Trung Nguyen and Steve Wereley

Reference Books

1. Introduction to Solid State Physics : Kittel
2. Introduction to Theory of Solids : H.M. Rosenberg
3. Theoretical Microfluidics by Henrik Bruus, Oxford
4. Introduction to Microfluidics by Tabeling, Oxford
5. Microdrops and digital microfluidics by Jean Berthier
6. The Structure and Rheology of Complex Fluids by R. Larson

(b) NANOPOLYMERS IN MEDICINE

Module I (10 hours)

Bionanotechnology today: Basic capabilities, Functional principles of Bionanotechnology: Information driven nano-assembly, Energetics, Chemical transformation, Regulation, Biomaterials, Biomolecular motors, Traffic across membranes, Biomolecular sensing, Self replication, Machine-Phase bionanotechnology.

Module II (10 hours)

Nanomedicine, Molecular design using biological selection, Harnessing molecular motors, Artificial life, Hybrid materials, Biosensors. Structural principles of Bionanotechnology: The raw materials; biomolecular structure and stability, Protein folding, Self assembly, Self-organization, Molecular recognition, Flexibility

Module III (12 hours)

Biomaterial based metallic nanowires, networks and circuitry: DNA as functional template for nanocircuitry; Protein based nanocircuitry; Neurons for network formation. DNA based nanomechanical devices. Biosensor and Biochips. Drug Delivery, Therapeutic action of nanoparticles and nanodevices- Targeted, non-targeted delivery; controlled drug release; exploiting novel delivery routes using nanoparticles; gene therapy using nanoparticles;

Module IV (12 hours)

Nanostructures for use as antibiotics, diseased tissue destruction using nanoparticles; diagnostics using nanomaterial, nanoparticles for bioanalytical applications - nanodevices for sensing and therapy. Use of nanoparticles for MRI, X Ray, Ultrasonography, Gamma ray imaging. Nanoparticles as molecular labels; biological labeling using quantum dots as molecular labels; Tissue Engineering.

Text Books

1. Nanotechnology Understanding Small Systems, Rogers Pennathur Adams, CRC Press, Taylor & Francis Group.
2. Gonsalves; Kenneth E., Halberstadt; Craig R., Laurencin; Cato T. And Nair; Lakshmi S.(Eds.), Biomedical Nanostructures, Wiley-Interscience, Hoboken (2008).
3. Chu; Paul K. and Liu; Xuanyong (Eds.), Biomaterials Fabrication and Processing Handbook, CRC Press, Boca Raton (2008)
4. Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology - Hari Singh Nalwa

Reference Books

1. Bionanotechnology: Lessons from Nature by David S. Goodsell
2. Nanocomposite Science & Technology Ajayan, Schadler & Braun
3. BioMEMS (Microsystems) - Gerald A. Urban
4. Nanosystems: Molecular Machinery, Manufacturing, and Computation - K. Eric Drexler
5. Nanobiotechnology; ed. C.M.Niemeyer, C.A. Mirkin.
6. Nanofabrication towards biomedical application: Techniques, tools, Application and impact – Ed. Challa S., S. R. Kumar, J. H. Carola.
7. Dendrimers I, II, III, Ed. F. Vogtle
8. Tissue Engineering-Bernhard O. Palsson , Sangeeta N. Bhatia
9. Principles of Tissue Engineering - Robert Lanza, Robert Langer, and Joseph P

5. ELECTIVE V (3-1-0) 3 Cr

(a) POLYMER BASED OPTICAL, ELECTRONIC & MAGNETIC MATERIALS

Module I (10 hours)

Introduction. Recent past, the present and its challenges, Future, Overview of basic Nanoelectronics. Molecular Electronics Components. Characterization of polyphenylene based switches and complex molecular devices. Molecular rectifying diode switches.

Module II (10 hours)

Nanophotonics: Background, Photonic Properties of Nanomaterials; Photon Absorption, Emission & Scattering; Permittivity & free Electron Plasma of metals, Extinction Coefficient of Metal particles; Gold & silver particles

Semiconductors: Tuning the Band gap of Nanoscale Semiconductors, Laser & uses of Quantum Dots, Lasers based on Quantum Confinement

Near Field Light, Optical Tweezers, Photonic Crystals

Module III (12 hours)

Semiconductor nanowires- Fabrication strategies, quantum conductance effects in semiconductor nanowires, porous Silicon, nanobelts, nanoribbons, nanosprings.

Nanoelectronic & Nanocomputer architectures: Introduction to nanoelectronic and nanocomputers, Quantum DOT cellular Automata (QCA), Single electron circuits, molecular circuits for Nanocomputer Architecture.

Module IV (12 hours)

Nanostructured ferromagnetism, effect of bulk nanostructuring of magnetic properties, dynamics of nanomagnets, Nanocarbon ferromagnets, Giant & colossal magnetoresistance, Nanopore containment of magnetic particles,

Text Books

1. Nanotechnology Understanding Small Systems, Rogers Pennathur Adams, CRC Press, Taylor & Francis Group.
2. Nanoelectronics & Nanosystems: From Transistor to Molecular & Quantum Devices: Karl Goser, Jan Dienstuhl and others.
3. Introduction to Nanotechnology - Charles P Poole Jr, Frank J Owens

Reference Books

1. Handbook of Semiconductor Nanostructures and Nanodevices Vol 1-5 - A. A. Balandin, K. L. Wang.
2. From Atom to Transistor-Supriyo Datta
3. Quantum Hetero-structures: Micro-electronics and opto-electronics, VV Mitin, VA Kochelap, MA Stroscio.

(b) NANOMATERIALS FOR ENERGY & ENVIRONMENT

Module I (8 hours)

Energy Overview: Energy Characteristics - Fundamentals of environment, Environmental impact assessment, Nanomaterials used in energy and environmental applications and their properties. Nanomaterials in automobiles.

Module II (10 hours)

Improvements in solar energy conversion and storage; better energy-efficient lighting; stronger and lighter materials that will improve energy transportation efficiency; use of low-energy chemical pathways to break down toxic substances for remediation and restoration; and better sensors and controls to increase efficiency in manufacturing and processing.

Module III (12 hours)

Device applications Energy – Hydrogen Storage and Production – Fuel Cells – Battery – Carbon Nanotubes for energy storage, Hydrogen Storage in Carbon Nanotubes, Use of nanoscale catalysts to save energy and increase the productivity in industry, Rechargeable batteries based on nanomaterials.

Module IV (12 hours)

Pollution by Nano-particles, Waste remediation: Nanoporous polymers and their applications in water purification, Photo-catalytic fluid purification. Energy conversion, Hierarchical self-assembled nano-structures for adsorption of heavy metals.

Text Books

1. W.F. Kenney: Energy Conservation in the Process Industries, Academic Press, 1984
2. Tetsuo Soga, Nanostructured Materials For Solar Energy Conversion, Elsevier
3. Robert K, Ian H, Mark G, Nanoscale Science and Technology, john Wiley & sons Ltd., 2005

PRACTICALS

6. NANOSCIENCE AND TECHNOLOGY LAB (0-0-3) 2 Cr

1. Synthesis of Nanomaterials - TiO_2, CdS, ZnO, $BaTiO_3$, $SrTiO_3$, hydroxyapatite & other nanoparticles
2. Processing & Fabrication of Polymer nanocomposites using Melt blending, Optimization of process parameters, extruder screws, design of experiments.
3. Solution Casting, Electrospinning process
4. Characterization of the above Nanomaterials using conventional methods viz XRD, XRF, FT-IR etc & other specific techniques based on End –use applications

7. POLYMER PROCESSING AND ADVANCED COMPUTER AIDED ENGINEERING TECHNIQUES (0-0-3) 2 Cr

1. Solution casting process for polymer nanocomposites
2. Multilayer extrusion blown film technique for polymer clay nanocomposite films
3. Compression moulding for fabrication of polymer clay nanocomposite sheets
4. Blow moulding for fabrication of polymer clay nanocomposite products
5. Mathematical modelling and engineering design analysis of polymer processing operations including extruder screws, injection molds, dies, fibers, film formation,
6. Mould flow simulation and Residual stress analysis.
7. Use of finite element programs to perform flow, cooling, and stress analysis of injection molded parts.

8. PRE-THESIS WORK AND SEMINAR II (0-0-3) 2 Cr

The student is required to study on an advanced topic relevant to the field. He/she will be examined through an oral presentation based on the study carried out in the second semester.

9. COMPREHENSIVE VIVA-VOCE I (0-0-3) 2 Cr

The student is required to appear for the Comprehensive Viva-Voce examination. This is an oral examination based on the courses (Theory, Laboratory and Seminar) undergone by the student in the second semester M. Tech. Programme.

THIRD SEMESTER

1. THESIS PART I 14 Cr

The project work starts in the third semester and extends to the end of the fourth semester. The project can be carried out at the institute or in an industry/research organization. At the end of the third semester, the students' thesis work shall be assessed and graded as per the Regulations for M. Tech.

2. OPEN ELECTIVE (3-1-0) 3 Cr

(a) BIODEGRADABLE PLASTICS AND ENVIRONMENTAL ENGINEERING

Module I (14 hours)

Plastics & environment, biodegradation of plastics, renewable resources, synthetic & natural plastics. Biodegradable starch based polymers, microbial polyamino acid, lignum, alginate based cellulose/PLA/PHA/Polyester, polysaccharides, chitin & chitosan – synthesis, structure and properties.

Module II (12 hours)

Disposal environments, plastics sorting & reprocessing – composting facilities & soil burial, aerobic/anaerobic biodegradation, waste water treatment plant, reprocessing facilities. Emerging application of biodegradable plastics: mulch film, shopping bags, consumer packaging materials, miscellaneous applications.

Module III (10 hours)

Concept of Environmental Engineering, scope and importance, environmental issues related to plastics industries. Noise in industry & its effect on human beings, methods to reduce noise pollution, heat stress and effect of over exposure to heat, industrial ventilations and exhaust systems.

Module IV (8 hours)

Polymers & energy, plastics in marine environment, environmental effects on polymeric materials. Environment, human population and health. Chemical safety managements, occupational health management.

References

1. G J L Griffin, Chemistry and Technology of Biodegradable Polymers, Blackie Academic Professional 1994
2. Gerald Scott & Dan Gilad, Degradable Polymer – Principles & Applications, Chapman & Hall 1995
3. Y Doi & K Fukuda (Eds), Biodegradable Plastics & Polymers, Elsevier 1994
4. S N Shalaby & K J L Burg, Absorbable & Biodegradable Polymers, CRC Press 2003
5. Cunningham, W.P. and Cunningham, M.A 2008 Environmental Science- a global concern. 10th edition McGraw Hill International, Boston
6. Anthony L. Andrady, Plastics and the environment, John Wiley & Sons, 2003
7. Plastics for environment & sustainable development ICPE & CIPET Publication 2003 Ed.
8. Bharucha, E. 2005 Textbook of Environmental Studies for undergraduate courses(for UGC) University Press, Hyderabad.
9. Miller, G.T 2006 Environmental Science 11th edition Brooks/Cole, Australia
10. Mc Graw Hills Hazardous Chemical Safety Guide for Plastics

(b) RECYCLING OF PLASTICS AND WASTE MANAGEMENT

Module I (8 hours)

Classification of Plastic Materials Natural and synthetic polymer and their compatibility with surroundings (starch and proteins, silicons and other man made fabrics). Life expectancy of different plastics in environment and thermal degradation, biodegradation and photo degradation. Agents for increasing life expectancy of polymers.

Module II (8 hours)

Pollution caused by plastics, loading of toxic chemicals from plastics into soil and water (including additives, flame retardants, chonnated additives etc.) ISI Standards regarding limits of these chemicals in effluents.

Module III (10 hours)

Reusability and Reprocessing of Plastics Need and importance of reprocessing. Stages in recycling (primary, secondary and tertiary), Advantages and disadvantages of recycling. Public awareness regarding hazards caused by indiscriminate use of plastics, proper disposal of plastics. Collection of recyclable plastics, Landfill. Incineration of plastics.

Module IV (8 hours)

Use of Plastics in Conservation of Natural Resources: Mulching, waste water recovery by membrane separation, use of plastics in rain water harvesting, plastic pipes for transportation of potable water (as compared to iron pipes) and canal lining.

References

1. Plastic Waste Management by Nabil Mustufa; Marcel Dekker
2. Chemistry of Waste Management by Clark
3. Elements of Polymer Degradation by Leo Rich and Stivala; McGraw Hill Company
4. Environmental Sanitation by Baljeet S Kapoor; S Chand and Company, New Delhi
5. Introduction to Environmental Engineering and Science by Gilbert M Masters; Prentice Hall of India, New Delhi
6. Recycling and Recovering of Plastics by Brandrup (Hanser Publications)

FOURTH SEMESTER

1. THESIS PART II **20 Cr**

At the end of the fourth semester, the student shall present his/her thesis work before an evaluation committee, which will evaluate the work and decide whether the student may be allowed to submit the thesis or whether he/she needs to carry out additional work.

2. SEMINAR **2 Cr**

3. COMPREHENSIVE VIVA VOCE II **(0-0-3) 2 Cr**

The student is required to appear for the Comprehensive Viva-Voce examination. This is an oral examination based on the courses (Theory, Laboratory and Seminar) undergone by the student in the second semester M. Tech. Programme.