Curriculum and Syllabi

M.Tech Degree Programme

in

NANOTECHNOLOGY

(with effect from Academic Year 2010-2011**)**

BRIEF SYLLABUS

तमसो मा ज्योतिर्गमय

SCHOOL OF NANO SCIENCE AND TECHNOLOGY

NATIONAL INSTITUE OF TECHNOLOGY, CALICUT

MA6001 Mathematical Methods

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Vector spaces - Linear Transformations - Range and Kernel – Isomorphism - Power series solutions - Legendre equation and Legendre polynomials - Bessel equation - First order PDEs - Linear equations - Lagrange method - Second order PDEs - Classifications - Line, area and volume integrals - Covariant and mixed tensors

Total Hours: 42

PH6001 Physics of Materials

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Quantum Mechanics: Introduction, Wave nature of matter, wave particle duality. Operators. Schrodinger Equation. Classification of condensed matter: crystalline and noncrystalline solids, liquids. Mesoscopic Physics. Superconductivity

Total Hours: 42

NS6101 Structure of Nanomaterials

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Classification of nanostructures, nanoscale architecture, fundamental structure, chemistry, property relationships in nanomaterials and nanomaterial systems. Electronic properties of atoms and solids, the isolated atom, bonding between atoms, giant molecular solids. Nanocrystalline materials, nanocomposities. Nanoscale x-ray -electron and neutron diffraction techniques,Scanning electron microscopy, Transmission electron microscopy , Atomic force microscopy (AFM), Scanning tunneling microscopy (STM).

Total Hours: 42

NS6102 Microscale and Nanoscale Heat Transfer

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Introduction and overview of studies on microscale heat transfer, Microscale Heat conduction, Phonon dispersion and phonon transport equations - conduction in integrated circuits and their constituent films, Fundamental of convective heat transfer in microtubes and channels, multiphase flow and gas flow in Microchannels, Conduction, convection and radiation in the nanoscale.

Total Hours: 42

NS6191 Nanoscience and Technology Lab-I

L	T	P	C
0	0	3	1

Prerequisite:- Nil

Selected experiments/problems from the following:

1. Preparation of Nanoparticle suspensions and sedimentation study
2. Onset of natural convection in nanofluids
3. Performance evaluation of nano fuel additives
4. Emission studies in nano fuel additives
5. Performance study on heat exchangers with nanofluids
6. Distillation characteristics of nanofluids
7. Burn-out phenomena in nanfluids
8. Molecular Dynamics simulation of thermal conductivity
9. Molecular Modeling of Boiling in nanofluids
10. Thermal Conductivity measurement using cut-bar apparatus

Total Hours: 42

NS6192 Seminar I

L	T	P	C
0	0	3	1

Prerequisite:- Nil

Each student shall prepare a paper on any topic of interest in the field of specialization – Nanotechnology. He/she shall get the paper approved by the Programme Coordinator/ Faculty in-charge and present it in the class in the presence of Faculty in-charge of seminar class. Every student shall participate in the seminar. Grade will be awarded on the basis of the student's paper, presentation and his/her participation in the seminar.

Total Hours: 42

NS6111 Nanosized Structures

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Design principles and implementation of nano-engineered materials in the development of nanotechnology applications. Novel structural functionality, sensory functionality, and information processing capabilities of nanomaterials. Molecular self-assembly phenomena, emerging hybrid material - system integration protocols-advanced topics in molecular materials and architectures;Nanoscale materials characterization, modeling, analysis, and metrology. Physical properties of nanostructured semiconductors critical to nanoscale optoelectronic devices.

Total Hours: 42

NS6112 Experimental Techniques in Nanotechnology

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Statistical principles for design-of-experiment methods as applied to nanomaterials Elementary ideas of blocking, general principles of linear model analysis. Experimental techniques for temperature measurement –Characterization techniques in nanotechnology - Micorscopy - Spectroscopic Methods –

Total Hours: 42

NS6113 Micro Electro Mechanical Systems and Applications

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Overview of micro electro mechanical devices and technologies. Introduction to architecture design, process flow, fabrication, packaging and testing. MEMS Fabrication - MEMS device concepts (micro sensors/actuators) - Use of capacitive, inductive, optical, piezoresistive, piezoelectric methods for sensing. MEMS Applications- Microsystems PackagingIntroduction to existing and next-generation metrology tools for MEMS and NEMS inspection and qualification.Cross-disciplinary application of MEMS and NEMS to the biological sciences.

Total Hours: 42

NS6114 Thermodynamics of Nano Materials and Systems

L	T	P	C
3	0	0	3

Prerequisite:- Nil

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-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

Total Hours: 42

NS6193 Nanoscience and Technology Lab-II

L	T	P	C
0	0	3	1

Prerequisite:- Nil

Selected experiments/problems from the following:

1. Experiments on liquid loops with water-based nanofluids
2. Interferometric measurements in dilute nanofluids
3. MD simulation of thermal conductivity of TIM
4. One step production – evaporation
5. CNT using CVD
6. Slip flow modeling in micro fin arrays
7. Lattice Boltzmann analysis of mixing
8. Characterization of nanoparticle suspensions
9. Development and Characterization of Nanocomposites.
10. Synthesis of soft nanomaterials

Total Hours: 42

NS6194 Seminar II

L	T	P	C
0	0	3	1

Prerequisite:- Nil

Each student shall prepare a paper on any topic of interest in the field of specialization – Nanotechnology. He/she shall get the paper approved by the Programme Coordinator/ Faculty in-charge and present it in the class in the presence of Faculty in-charge of seminar class. Every student shall participate in the seminar. Grade will be awarded on the basis of the student's paper, presentation and his/her participation in the seminar.

Total Hours: 42

NS7198 Project

L	T	P	C
0	0	0	8

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 by a committee and graded as specified in the "Ordinances and Regulations for M. Tech.".

NS7199 Project

L	T	P	C
0	0	0	12

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. The final viva-voce examination will be conducted as per the "Ordinances and Regulations for M. Tech.".

NS6121 Mechanics of Finite-size Elements

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Conitnuum solid mechanics – deformation, strain and stress tensors, equilibrium, strain displacement and constitutive equations, micromechanics applications – dislocation modeling and Doublet mechanics, mesoscale applications & homogenization, foundations of Nanomechanics, virial stress tensor, introduction to computation methods, fracture, deformations, creep and fatigue of nanoscale systems.

Total Hours: 42

MA6005 Optimization Techniques

L	T	P	C
3	0	0	3

Prerequisite:- Nil

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 -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

Total Hours: 42

ME6212 Computational Methods in Fluid Flow and Heat Transfer

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Numerical solution of partial differential equations, computational economy, numerical error, convergence, relaxation, tri diagonal algorithm, discretization, application to heat conduction problems, Dirichlet, Neumann and Robbins boundary conditions, Crank Nicholson and ADI methods, conservation form and conservative property of PDE, finite volume method for diffusion and convection diffusion problems, vorticity approach, SIMPLE, SIMPLER algorithms, numerical marching techniques.

Total Hours: 42

NS6122 Nano Materials for Energy and Environment

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Energy Overview: Energy Characteristics - Fundamentals of environment Environmental impact assessment Nanomaterials used in energy and environmental applications and their properties. Device applications Energy – Hydrogen Storage and Production – Fuel Cells – Battery – Solar energy conversion - Nanomaterials in Automobiles

Total Hours: 42

NS6123 Management Of Technology And Innovation

L	T	P	C
3	0	0	3

Prerequisite:- Nil

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

Total Hours: 42

EE6121 Data Acquisition and Signal Conditioning

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Data Acquisition Systems(DAS)- Signal Conditioning: Requirements – Instrumentation amplifiers: Basic characteristics .Review of Nyquist.s Sampling Theorem-First and second order filters - classification and types of filters -. Design of Higher Order Filters using second order sections using Butterworth Approximation-Narrow Bandpass and Notch Filters and their application in DAS. Sample and Hold Amplifiers Analog-to-Digital Converters(ADC)- Multiplexers and demultiplexers - Digital multiplexer . A/D Conversion- Digital-to-Analog Conversion(DAC) .Multiplying Type DAS Boards- Modular Programming Techniques for Robust Systems, Bus standard for communication between instruments - GPIB (IEEE-488bus) - Interrupt-based Data Acquisition.Software Design Strategies

Total Hours: 42

NS6124 Computational Nanotechnology

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Need for discrete computations, classical mechanics – Hamilton's principle and Lagrange's equations, statistical mechanics – quantum states, ensembles, partition function, equipartition theorem and Maxwell distribution of molecular speeds, Atomistic simulation techniques – Molecular Dynamics and Monte Carlo methods, Mesoscopic methods – Lattice Boltzmann method and Dissipative Particle Dynamics, Introduction to Multiscale methods

Total Hours: 42

ME6325 Finite Elements Method and Applications

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Basic concepts – steps involved in finite element analysis – Variational methods of approximation – Galerkin's method – shape functions – Family of elements – Assembly and solution techniques – One dimensional problems. Analysis of scalar and vector field problems – Finite element analysis of fluid mechanics and heat transfer problems. Elasticity problems – Two and three dimensional elasticity problems – Bending of beams – bending of elastic plate. Eigen value and time dependent problems - Non-linear problems – Finite element error analysis – Automatic mesh generation.

Total Hours: 42

NS6125 Carbon Nanotube Science and Technology

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Introduction to Carbon-Nanotube Science and Technology - Mechanical Properites and thermal stability of carbon nanotubes –Heat transport in MWNTS - Introduction to optical response of Carbon Nanotubes – Excitonic effects – Optical spectra of SWNTs –Overview of Resonance Raman Spectroscopy – Photoluminescence spectroscopy of nanotubes –Rayleigh scattering spectroscopy –Magnetic phenomena in carbon nanotubes –Introduction to Carbon nanotube optolectronics- Overview of CNT electronics – Electrical transport in Carbon Nanotubes – Quantum transport – Quantum dots Recent advances

Total Hours: 42

ME6511 Composite Materials: Mechanics, Manufacturing and Design

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Composite materials, geometric morphology, advanced matrix, fibers and interfaces, manufacturing composites. Unidirectional composites, Analysis of laminated composites through computers, hygrothermal stresses, fatigue failure mechanisms, experimental characterization of composites. Composite structures, properties of composite sections and stiffened panels, laminated beams, plates, shells and composite structural design.

Total Hours: 42

NS6126 Combustion and Nanoparticle Fuel-additives

L	T	P	C
3	0	0	3

Prerequisite:- Nil

I.C. Engines- A/F ratio requirements- Ignition temperature- Ignition delay- Chemical Kinetics -Normal combustion in SI engines - Knocking – Effect of variable on knocking tendency – Octane number – Normal combustion in CI Engines- Theories of detonation - Cetane number – Cetane index – Fuels for I.C. Engines - Fuel additives -Properties of fuels- Nano fuel additives – Nano fluid preparation – effect of nano particle on fuel properties –Air pollution – Engine emission measurement – Emission control devices –Exhaust Gas Recirculation

Total Hours: 42

NS6127 Polymer Chemistry

L	T	P	C
3	0	0	3

Prerequisite:- Nil

Introduction to Polymers,Compounding and processing of polymers, Additives for compounding plastics, additives for compounding of rubbers, two roll mill, banbury mixer, pigments, processing aids, processing methods for the manufacture of products, blending and mastication, masterbatching, mixing and compounding, calendaring, extrusion and moulding. Different elastomer curing systems-Testing of Rubbers. thermal analysis such as TGA, TMA, and DSC. Introduction to polymer melt rheology, viscosity,

Total Hours: 42

Curriculum and Syllabi

M.Tech Degree Programme

in

NANOTECHNOLOGY

(with effect from Academic Year 2010-2011**)**

DETAILED SYLLABUS

SCHOOL OF NANO SCIENCE AND TECHNOLOGY

NATIONAL INSTITUE OF TECHNOLOGY, CALICUT

MA6001 Mathematical Methods

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 Linear Algebra (11 Hours)
Vector spaces, Basis, Dimension, Inner product spaces, Gram-Schmidth Process, Linear Transformations, Range and Kernel, Isomorphism, Matrix of transformations and Change of Basis.

Module 2 Series Solutions of ODE and Sturm-Liouville Theory (10 Hours)
Power series solutions about ordinary point, Legendre equation and Legendre polynomials, Solutions about singular points; The method of Frobenius, Bessel equation and Bessel Functions. Sturm-Liouville problem and Generalized Fourier series.

Module 3 Partial Differential Equations (11 Hours)
First order PDEs, Linear equations, Lagrange method, Cauchy method, Charpits method, Jacobi method. Second order PDEs, Classifications, Formulation and method of solutions of Wave equation, Heat equation and Laplace equation.

Module 4 Tensor Calculus (10 Hours)
Line, area and volume integrals, Spaces of N-dimensions, coordinate transformations, covariant and mixed tensors , fundamental operation with tensors, the line element and metric tensor, conjugate tensor, Christoffel's symbols , covariant derivative.

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. Sokolnikoff, I. S. and Redheffer, R. M., Mathematics of Physics and Modern Engineering, Second Edition,McGraw-Hill, 1966.
6. Sneddon, I., Elements of Partial Differential Equations, McGraw-Hill, 1985.
7. Tychonov, A. N. and Samarskii, A. A., Partial Differntial Equations of Mathematical Physics, Holden-Day, 1964.
8. Spain, B., Tensor Calculus, Third Edition, Oliver and Boyd, 1965.
9. Irving, J. and Mullineux, N., Mathematics in Physics and Engineering, Academic Press, 1959.
10. Ross, S. L., Differential Equations, Third Edition, John Wiley & Sons, 2004.
11. Pipes, L. A. and Harwill, L. R., Applied Mathematics for Engineers and Physicists, Third Edition, McGraw-Hill, 1970.
12. Akivis, M. A. and Goldberg, V. V., An Introduction to Linear Algebra and Tensors, Dover Publications, 1997.

PH6001 Physics of Materials

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (10 Hours)
Quantum Mechanics: Introduction, Wave nature of matter, wave particle duality. Operators. Schrodinger Equation , Wave function and its properties. Uncertainty principle. Application of Schrodinger equation to general problems.

Module 2 (10 Hours)

Classification of condensed matter: crystalline and noncrystalline solids, liquids. Crystalline solids: Bonding and internal structure. K- space, Momentum space, Reciprocal lattice and lattice vector. X-Ray, Neutron, and Electron diffraction of waves by crystals: Bragg's law in direct and reciprocal lattice. Structure factor. Brillouin zones. Excitations in solids: Excitons and Polarons

Module 3 (12 Hours)

Dependence of electron energy on the wave vector, E-K diagram., Free electron theory of metals. Density of States. Thermal and Electrical transport properties.. Fermi surface. Energy spectra of atoms, molecules and solids - formation of energy bands. Electrons in periodic potential;. Bloch theorem. Electron states and classification into insulators, conductors and semimetals. Effective mass and concept of holes.
Glassy state and glass transition temperature, crystallization and melting –phase transformations; first order and second order phase transformations. Arrhenius type dependence. . Measurement techniques for glass transition temperature and heat capacity – Differential Scanning Calorimetry.

Module 4 (10 Hours)
Mesoscopic Physics, Quantum wire, well and dot. Fundamentals of nano technology: Size, and interference effects. Quantum confinement and Coulomb blockade.
Superconductivity. Meissner effect, London equation, Type I and II superconductors, Superconducting band gap, Cooper pairs, flux quantization. BCS theory (qualitative). High Temperature superconductors. Conducting polymers

References

1. Eisberg, Resnick, Quantum Physics, Wiley (2006)
2. M.A.Omer Elementary Solid State Physics. Adison Wesley (2007)
3. Kittle, C.: Introduction to Solid State Physics, Wiley (2007)
4. C M Kachhava: Solid State Physics, TMH (2005)
5. Rosenberg: Introduction to Solid State Physics, Oxford University Press (1995)

NS6101 Structure of Nanomaterials

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (12 Hours)
Classification of nanostructures, nanoscale architecture, fundamental structure, chemistry, property relationships in nanomaterials and nanomaterial systems. Top-down processes, bottom-up processes, methods for templating the growth of Nanomaterials Ordering of nanosystems, preparation, safety and storage issues

Module 2 (10 Hours)
Electronic properties of atoms and solids, the isolated atom, bonding between atoms, giant molecular solids, the free electron model and energy bands, band theory, crystallography, fundamentals of mechanical, electrical and magnetic properties of nanomaterials.

Module 3 (10 Hours)
Nanocrystalline materials, nanocomposities, quantum well structures, extreme ultraviolet (EUV) optical elements and grain size determination in nanomaterials and nanometer scale systems.

Module 4 (10 Hours)
Nanoscale x-ray -electron and neutron diffraction techniques, Application areas, Scanning electron microscopy, Transmission electron microscopy , Atomic force microscopy (AFM), Scanning tunneling microscopy (STM).

References

1. Callister, William D. Jr., Fundamentals of Materials Science and Engineering: An Integrated Approach 2nd Ed., John Wiley and Sons, 2003
2. S. N. Sahu, R. K. Choudhury, and P. Jena, Nano-scale Materials: From Science to Technology, Nova Science Publishers, 2006.
3. Yannick Champion , Hans-Jörg Fecht, Nano-Architectured and Nanostructured Materials: Fabrication, Control and Properties, Wiley-VCH,2005.
4. Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2005

NS6102 Microscale and Nanoscale Heat Transfer

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (10 hours)
Introduction to microscale heat transfer - Observations on deviations from conventional theory – experimental and theoretical findings – Overview of studies and comparison of results – Introductory ideas about single phase, multiphase and gas flow in small channels – Contradictory observations and view points in microchannel heat transfer- Applications of microscale heat transfer – basic ideas on micro heat exchangers and microscale heat sinks – applications in electronics cooling, biotechnology and MEMS.

Module 2 (8hours)
Conduction in integrated circuits and their constituent films – current trends and future challenges – Microscale thermometry techniques – electrical and optical methods – thermorefectance thermometry – Thermal properties of amorphous dielectric films – Thermal characterization and heat transport in dielectric films – Heat conduction in crystalline silicon films – Phonon dispersion - heat conduction in semi-conductors at high temperatures – phonon transport equations – hot phonon effects.

Module 3 (12 hours)
Fundamentals of convective heat transfer in microtubes and channels – Thermodynamic concepts, general laws and particular laws - Governing equations and size effects. Single phase forced convection in microchannels – Flow structure – entrance length – experimental observations on flow and heat transfer characteristics – Theoretical investigations – Forced convection in mixtures - Gas flow in microchannels. Boiling and two- phase flow heat transfer in small channels – Boiling curve and critical heat flux - flow patterns – Bubble dynamics and thermodynamic aspects – Mathematical modeling and measurement of microscale convective boiling; Applications of microchannel heat transfer – microchannel heat sinks – micro heat pipes and micro heat spreaders – integration of microchannel heat sinks and heat spreaders to silicon structures – experimental and theoretical investigations.

Module 4 (12 hours)
Fundamentals of heat transport at the nanoscale – characteristic lengths and heat transfer regimes – Nanoscale heat transfer phenomena – Conduction, radiation and convection in the nanoscale – Applications of nanoscale heat transfer in microelectronics, energy, nanomaterial synthesis, nano fabrication and biotechnology – Experimental methods in nanoscale heat transfer – thermophysical property measurement – heating and sensing based on microheaters and microsensors – Photothermal methods – Mixed optical and electrical heating methods – Nanowires and carbon nanotubes – Thermal imaging – Analytical methods – Boltzmann equation approach and Monte Carlo Simulation for Boltzmann transport equation – The wave mechanisms - quantized incoherent transport, molecular dynamics simulation and the fluctuation-dissipation theorem approach – Multicarrier and Multidimensional Transport – coupled electron-phonon transport, multi length-scale and multidimensional transport – Challenges and Future applications.

References

1. C B Sobhan, G P Peterson, Microscale and Nanoscale Heat Transfer-Fundamentals and Engineering Applications, Taylor and Francis/CRC, 2008.
2. Ju, Y.S., and Goodson, K. , Microscale Heat Conduction in Integrated Circuits and their Constituent Films, Kluwer Academic Publishers, Boston, 1999.
3. Satish, K., Srinivas, G., Dongqing, L., Stephane, C., and Michael R. K., Heat Transfer and Fluid Flow in Minichannels and Microchannels, First Edition,
4. Chen, G., Nanoscale Energy Transport and Conversion, Oxford University Press, 2005.
5. Mohamed Gad – el – Hak (ed.), The MEMS Handbook, Second Edition, CRC Press, 2005.

NS6191 Nanoscience and Technology Lab-I

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
0	0	3	1

Selected experiments/problems from the following:

1. Preparation of Nanoparticle suspensions and sedimentation study
2. Onset of natural convection in nanofluids
3. Performance evaluation of nano fuel additives
4. Emission studies in nano fuel additives
5. Performance study on heat exchangers with nanofluids
6. Distillation characteristics of nanofluids
7. Burn-out phenomena in nanfluids
8. Molecular Dynamics simulation of thermal conductivity
9. Molecular Modeling of Boiling in nanofluids
10. Thermal Conductivity measurement using cut-bar apparatus

NS6192 Seminar I

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
0	0	3	1

Each student shall prepare a paper on any topic of interest in the field of specialization – Nanotechnology. He/she shall get the paper approved by the Programme Coordinator/ Faculty in-charge and present it in the class in the presence of Faculty in-charge of seminar class. Every student shall participate in the seminar. Grade will be awarded on the basis of the student’s paper, presentation and his/her participation in the seminar.

NS6111 Nanosized Structures

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (10 Hours)
Design principles and implementation of nano-engineered materials in the development of nanotechnology applications.

Module 2 (11 Hours)
Novel structural functionality, sensory functionality, and information processing capabilities of nanomaterials. Integration and fabrication paradigms of such functional materials in nanotechnology.

Module 3 (11 Hours)
Molecular self-assembly phenomena, emerging hybrid material - system integration protocols -advanced topics in molecular materials and architectures; optoelectronic materials, architectures, and devices; nanosystems sciences and technologies; thin film single and multilayered material structures;

Module 4 (10 Hours)
Nanomaterials for nanotechnology - Nanoscale materials characterization, modeling, analysis, and metrology. Physical properties of nano-structured semiconductors critical to nanoscale optoelectronic devices.

References

1. K. E. Drexler, Engines of Creation (Fourth Estate, London, 1990).
2. E. Regis, Nano. The Emerging Science of Nanotechnology: Remaking the World – Molecule (Little-Brown, Boston, 1995).
3. J. P. Sauvage, (ed.), Structure and Bonding, Vol. 99 (Springer-Verlag, Heidelberg, 2001).
4. G. M. Whitesides and B. Grzybowski, Self-assembly at all scales. Science 295, 2418 (2002).
5. Robert K, Ian H, Mark G, Nanoscale Science and Technology, john Wiley & sons Ltd.,2005

NS6112 Experimental Techniques in Nanotechnology

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (10 hours)
Statistical principles for design-of-experiment methods as applied to nanomaterials selfassembly, processing, and associated development of analytical protocols. Elementary ideas of blocking, general principles of linear model analysis. Introduction to replication, covariance, experimental treatment structures, and full- and partial-factorial designs.

Module 2 (8 hours)
Experimental techniques for temperature measurement – thermoreflectance thermometry – measurement of thermal phenomena in nanofluids – thermal conductivity measurement in nanofluids using steady state and transient methods.

Module 3 (12 Hours)
Characterization techniques in nanotechnology - Micorscopy - instrumentation and application, Sample preparation - contrast mechanisms - Scanning probe microscopy, tapping mode, contact mode, phase image, Scanning electron microscopy, Transmission electron microscopy and HRTEM, Scanning tunneling microscopy, Optical microscopy, Scanning near field microscopy - Electron back scattering - X-ray micro analysis.

Module 4 (12 Hours)
Spectroscopic Methods - Fundamental principles and experimental implementation of xray/electron diffraction, Raman spectroscopy - Auger Electron Spectroscopy, X-Ray Photoelectron Spectroscopy, Secondary Ion Mass Spectrometry, Energy-dispersive X-ray Spectroscopy.

References

1. Robert K, Ian H, Mark G, Nanoscale Science and Technology, john Wiley & sons Ltd.,2005
2. Weilie Zhou and Zhong Lin Wang, Scanning Microscopy for Nanotechnology, Springer 2006.
3. Nan Yaho and Zhong, Hand book of Microscopy for Nanotechnology, Kluwer Academic press, Boston, 2005.
4. K.S Birdi, Scanning Probe Microscopy, CRC Press, 2003.
5. C B Sobhan, G P Peterson, Microscale and Nanoscale Heat Transfer-Fundamentals and Engineering Applications, Taylor and Francis/CRC, 2008.
6. Ernest O Doeblin., "Measurement Systems: Application and Design", McGraw Hill (Int. Edition) 1990.

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NS6113 Micro Electro Mechanical Systems and Applications

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (12 Hours)
Overview of micro electro mechanical devices and technologies. Introduction to architecture design, process flow, fabrication, packaging and testing. MEMS Fabrication -Deposition, lithography, and etching – Surface micromachining - Bulk micromachining - bonding technologies, LIGA technology and related fabrication methods

Module 2 (12 Hours)
MEMS device concepts (micro sensors/actuators) - Use of capacitive, inductive, optical, piezoresistive, piezoelectric methods for sensing. MEMS Applications-Accelerometers and gyros - Pressure sensors - Micro optics, etc. Microsystems Packaging

Module 3 (9 Hours)
Introduction to existing and next-generation metrology tools for MEMS and NEMS inspection and qualification. Theoretical principles of metrology and experimental work on characterization of prototype MEMS and NEMS devices.

Module 4 (9 Hours)
Cross-disciplinary application of MEMS and NEMS to the biological sciences. Interaction of living cells/tissues with nanofabricated structures, microfluidics for the movement and control of solutions - the development of I/O architectures for efficient readout of bioreactions.

References
1. Mohamed Gad – el – Hak (ed.), The MEMS Handbook, Second Edition, CRC Press, 2005.
2. James J. Allen , Micro Electro Mechanical System Design, CRC, 2005.
3. K. Subramanian , Micro Electro Mechanical Systems: A Design Approach, Springer, 2008.

NS6114 Thermodynamics of Nano Materials and Systems

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (12 hours)
First Law of Thermodynamics, heat, work, heat capacity, enthalpy and internal energy, Hess' Law- and Second Law of Thermodynamics – Entropy and Criterion for Equilibrium – Statistical interpretation of entropy – Boltzmann equation.

Module 2 (10 hours)
Auxiliary Functions – Thermodynamic Relations – Maxwell's Equations – Gibbs - Helmholtz Equation – Examples – Heat capacity, enthalpy, entropy and the third law of Thermodynamics- First, second, and third laws of thermodynamics as applied to nanoscale systems

Module 3 (10 hours)
Phase Equilibrium in a one – Component system- Solid – Solid Equilibria – examples Gibbs free energy – Composition and Phase diagrams of binary Systems – Criteria for Phase stability – Thermodynamics and kinetics of phase transformations- Homogeneous nucleation- Heterogeneous nucleation - Growth and overall transformation rate

Module 4 (10 hours)
Physical phenomena of small systems - nano-crystalls, macromolecules, thermodynamics and physical properties of long chain molecules and molecular structures

References

1. David V. Ragone, Thermodynamics of Materials, Volume I, J. W. Wiley 1995.
2. Thermodynamics in Materials Science, By Robert T. DeHoff, McGraw-Hill, 1993.
3. Stoichiometry and Thermodynamic Computations in Metallurgical Processes, Y.K. Rao, Cambridge University Press, 1985.
4. Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2005
5. Daniel V. Schroeder: An Introduction to Thermal Physics, Addison-Wesley, 2000.

NS6193 Nanoscience and Technology Lab-II

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
0	0	3	1

Selected experiments/problems from the following:

1. Experiments on liquid loops with water-based nanofluids
2. Interferometric measurements in dilute nanofluids
3. MD simulation of thermal conductivity of TIM
4. One step production – evaporation
5. CNT using CVD
6. Slip flow modeling in micro fin arrays
7. Lattice Boltzmann analysis of mixing
8. Characterization of nanoparticle suspensions
9. Development and Characterization of Nanocomposites.
10. Synthesis of soft nanomaterials

NS6194 Seminar II

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
0	0	3	1

Each student shall prepare a paper on any topic of interest in the field of specialization – Nanotechnology. He/she shall get the paper approved by the Programme Coordinator/ Faculty in-charge and present it in the class in the presence of Faculty in-charge of seminar class. Every student shall participate in the seminar. Grade will be awarded on the basis of the student's paper, presentation and his/her participation in the seminar.

NS7198 Project

L	T	P	C
-	-	-	8

The project work starts in the third semester and extends to the end of the fourth semester. The student will be encouraged to fix the area of work and conduct the literature review during the second semester itself. The topic shall be research and development oriented. The project can be carried out at the institute or in an industry/research organization. Students desirous of carrying out project in industry or other organization have to fulfill the requirements as specified in the "Ordinances and Regulations for M. Tech. under the section - Project Work in Industry or Other Organization."
At the end of the third semester, the students' thesis work shall be assessed by a committee and graded as specified in the "Ordinances and Regulations for M. Tech.". If the work has been graded as unsatisfactory, in the third semester the committee may recommend a suitable period by which the project will have to be extended beyond the fourth semester.

NS7199 Project

L	T	P	C
-	-	-	12

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. The final viva-voce examination will be conducted as per the "Ordinances and Regulations for M. Tech.".

NS6121 Mechanics of Finite-size Elements

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 Continuum Solid Mechanics: (12 hours)

Mathematical preliminaries - scalar, vector and tensor quantities, deformation and strain tensors, strain-displacement relations, stress tensors, equilibrium equations, constitutive relations for elastic and elasto-plastic material behaviour, formulation and applications.

Module 2 Micromechanics Applications: (12 hours)
Fundamentals, dislocation modeling, singular stress states, distributed cracks and voids, micropolar elasticity, Doublet mechanics. Mesoscale applications - heterogeneous media and homogenization.

Module 3 Nanomechanics: (9 hours)
Introduction, concepts from classical and statistical mechanics, Virial stress tensor, introduction to computational methods, applications to nanomechanics of nanoscale systems and mechanics of nanoscale assemblies.

Module 4 Miscellaneous Topics in Nanomechanics: (9 hours)
Introduction to fracture mechanics, dislocation mediated deformation mechanisms, fracture and deformation of nanoscale solids, introduction to creep and fatigue of nanoscale structures.

References:

1. Sadd, Martin H., Elasticity – Theory, Applications and Numerics, Academic Press, 2006.
2. Liu, Wing Kam, Karpov, E.G., and Park, H.S., Nanomechanics and Materials, John Wiley & Sons, 2006.
3. Cleland, A.N, Foundations of Nanomechanics, Springer Verlag, 2005
4. Robert, K., Ian, H., Mark, G., Nanoscale Science and Technology, John Wiley & Sons, 2005.

MA6005 Optimization Techniques

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (10 Hours)
Elementary Linear Programming: Systems of linear equations & inequalities – Convex sets – Convex functions – Formulation of linear programming problems - Theory of Simplex method – Simplex Algorithm – Charne's M-Method – Two phase method – Duality in linear programming – Dual Simplex method

Module 2 (10 Hours)
Advanced Linear Programming: Sensitivity analysis – Parametric programming – Bounded Variables problem – Transportaion problem – Integrality property – MODI method – Degeneracy – Unbalanced problem – Assignment Problem – Development of Hungarian method – Routing problem.

Module 3 (12 Hours)
Dynamic Programming and Game Theory: Nature of Dynamic Programming problem – Bellmann's optimality principle. Cargo loading problem – Replacement problem – Multistage production planning and allocation problem – Rectangular Games – Two person – zero sum games – Pure and mixed strategies – 2 x n and m x 2 games. Relation between theory of games and linear programming

Module 4 (10 Hours)
Network Path Models: Tree Networks – Minimal Spanning Tree –Kruskal's Algorithm ,Prim's Algorithm- Shortest path problems – Solution methods – Dijkstra's Method – Floyd's Algorithm – Network flow Algorithms – Maximal flow algorithm – The method of Ford and Fulkerson

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. Taha. H. A. Operations Research – An introduction, Prentice Hall, India, VI edition, 1999.
6. Foulds L.R. Graph Theory Applications , Springer (Narosa) , Delhi , 1992

ME6212Computational Methods in Fluid Flow and Heat Transfer

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (10 hours)
Experimental, theoretical and numerical methods of predictions; physical and mathematical classifications partial differential equations; computational economy; numerical stability; validation of numerical results; round-off-error and accuracy of numerical results; iterative convergence, condition for convergence, rate of convergence; under – and over – relaxations, termination of iteration; tridiagonal matrix algorithm; discretization – converting derivatives to their finite difference forms – Taylor’s series approach, polynomial fitting approach; discretization error.

Module 2 (12 hours)
Steady one-dimensional conduction in Cartesian and cylindrical coordinates; handling of boundary conditions; two – dimensional steady state conduction problems in Cartesian and cylindrical co-ordinates– point-by-point and line-by-line method of solution, dealing with Dirichlet, Neumann, and Robins type boundary conditions; formation of discritized equations for regular and irregular boundaries and interfaces; grid generation methods; adaptive grids.

Module 3 (10 hours)
One-, two, and three-dimensional transient heat conduction problems in Cartesian and cylindrical co-ordinates – explicit, implicit, Crank-Nicholson and ADI schemes; stability criterion of these schemes; conservation form and conservative property of partial differential and finite difference equations; consistency, stability and convergence for marching problems; discrete perturbation stability analysis, Fourier or von Neumann stability analysis.

Module 4 (10 hours)
Finite volume method for diffusion and convection–diffusion problems – steady one dimensional convection and diffusion; upwind, hybrid and power-law schemes, discretization of equation for two-dimension, false diffusion; computation of the flow field using stream function–vorticity formulation; SIMPLE, SIMPLER, SIMPLEC and QUICK schemes, solution algorithms for pressure–velocity coupling in steady flows; numerical marching techniques, two-dimensional parabolic flows with heat transfer.

References

1. Anderson, D. A, Tannehill, J. C., and R. H. Pletcher, R. H., Computational Fluid Mechanics and Heat Transfer, Second Edition, Taylor & Francis, 1995.
2. Muraleedhar, K. and T. Sundararaja, T. (eds.), Computational Fluid Flow and Heat Transfer, Second Edition, Narosa Publishing House, 2003.
3. Patankar, S. V., Numerical Heat Transfer and Fluid Flow, Hemisphere, 1980.
4. Versteeg, H. K. and W. Malalasekera, W., An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Addison Wesley – Longman, 1995.
5. Hornbeck, R. W., Numerical Marching Techniques for Fluid Flows with HeatTransfer, NASA, SP – 297, 1973.

NS6122 Nano Materials for Energy and Environment

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (12 hr)
Energy Overview: Types of Energy and its utilization- Energy Characteristics – Energy Measures – Fundamentals of environment – Environmental aspects of energy utilization – Public health issues related to environmental pollution – Pollution Standards – environmental impact assessment

Module 2 (10 hr)
Nanomaterials used in energy and environmental applications and their properties. Evaluation of properties and performance of practical power systems that benefit from optimization of materials processing approaches.

Module 3 (10 hr)
Device applications - sensors, power semiconductor chips, fuel cells, superconductors, solar cells, energy storage and other alternative power sources.

Module 4 (10 hr)
Energy – Hydrogen Storage and Production – Fuel Cells – Battery – Solar energy conversion - Nanomaterials in Automobiles

References

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

NS6123 Management of Technology And Innovation

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (12 Hours)
Understanding Management of Technology, Key concepts – importance – issues. Process of technological change – innovation technology evaluation, Diffusion.

Module 2 (10 Hours)
Technology and competition, technology acquisition. Integration of strategic planning and technology planning. Key performance factors for technology management.

Module 3 (10 Hours)
Technology Strategy: - Technology intelligence – collaborative mode, Appropriation of technology – Deployment in new products, simultaneous engineering, Development in the value chain.

Module 4 (10 Hours)
Technology evaluation and financing – changing role of R & D, Management of manufacturing technology – corporate cultures – technology audits.

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..

EE6121Data Acquisition and Signal Conditioning

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 Transducers & Signal Conditioning (11 Hours):
Data Acquisition Systems(DAS)- Introduction . Objectives of DAS. Block Diagram Description of DAS-General configurations - Single and multichannel DAS-Transducers for the measurement of motion, force, pressure, flow, level, dc and ac voltages and currents (CTs, PTs for supply frequency as well as high frequency, Hall Effect Current Sensors, High Voltage Sensors , Optosensors, Rogowski Coil, Ampflex Sensors etc.) - Signal Conditioning: Requirements - Instrumentation amplifiers: Basic characteristics . Chopped and Modulated DC Amplifiers-Isolation amplifiers - Opto couplers - Buffer amplifiers .Noise Reduction Techniques in Signal Conditioning- Transmitters .Optical Fiber Based Signal Transmission-Piezoelectric Couplers- Intelligent transmitters.

Module 2 Filtering and Sampling (10 Hours):
Review of Nyquist.s Sampling Theorem-Aliasing . Need for Prefiltering-First and second order filters - classification and types of filters - Low -pass, High-pass, Band-pass and Band rejection and All Pass: Butterworth, Bessel, Chebyshev and Elliptic filters . Opamp RC Circuits for Second Order Sections-Design of Higher Order Filters using second order sections using Butterworth Approximation-Narrow Bandpass and Notch Filters and their application in DAS. Sample and Hold Amplifiers

Module 3 Signal Conversion and Transmission (10 Hours):
Analog-to-Digital Converters(ADC)-Multiplexers and demultiplexers - Digital multiplexer. A/D Conversion. Conversion Processes, Speed, Quantization Errors . Successive Approximation ADC. Dual Slope ADC. Flash ADC. Digital-to-Analog Conversion (DAC). Techniques, Speed, Conversion Errors, Post Filtering- Weighted Resistor, R-2R, Weighted Current type of DACs- Multiplying Type DAC-Bipolar DACs-Data transmission systems- Schmitt Trigger-Pulse code formats- Modulation techniques and systems-Telemetry systems.

Module 4 Digital Signal Transmission And Interfacing (11 Hours):
DAS Boards-Introduction . Study of a representative DAS Board-Interfacing Issues with DAS Boards, I/O vs Memory Addressing, Software Drivers, Virtual Instruments, Modular Programming Techniques for Robust Systems, Bus standard for communication between instruments - GPIB (IEEE-488bus) - RS-232C-USB-4-to-20mA current loop serial communication systems.Communication via parallel port . Interrupt-based Data Acquisition.Software Design Strategies-Hardware Vs Software Interrupts-Foreground/ background Programming Techniques- Limitations of Polling . Circular Queues

References

1. Ernest O Doeblin., "Measurement Systems: Application and Design", McGraw Hill (Int. edition) 1990.
2. George C.Barney, "Intelligent Instrumentation ", Prentice Hall of India Pvt Ltd., New Delhi, 1988.
3. Ibrahim, K.E., "Instruments and Automatic Test Equipment", Longman Scientific & Technical Group Ltd., UK, 1988.
4. John Uffrenbeck, "The 80x86 Family ,Design, Programming, And Interfacing", Pearson Education, Asia,
5. Bates Paul, "Practical digital and Data Communications with LSI", Prentice Hall of India, 1987.
6. G.B. Clayton, .Operational Amplifiers.,Butterworth &Co,
7. A.K Ray et. Al ,.Advanced Microprocessors and Peripherals., Tata McGrawHill,
8. Oliver Cage, .Electronic Measurements and Instrumentation, McGraw-Hill, (Int. edition) 1975.

NS6124 Computational Nanotechnology

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (11 hours)

Introduction: Computational simulation, need for discrete computation.
Classical Mechanics: Mechanics of Particles, D'Alembert's principle and Lagrange's equation, variational principles, Hamilton's principle, conservation theorems and symmetry properties, central force problems, virial theorem.

Module 2 (11 hours)

Statistical Mechanics: Review of probability and statistics, quantum states of a system, equations of state, canonical and microcanonical ensemble, partition function, energy levels for molecules, equipartition theorem, minimizing the free energy, partition function for identical particles, Maxwell distribution of molecular speeds.

Module 3 (10 hours)

Atomistic Simulation Techniques:
Molecular Dynamics (MD): Introduction, inter-atomic potential function, Lennard-Jones potential, MD simulation – equilibration and property evaluation, various types of potential functions, computational aspects, introduction to advanced topics.
Monte Carlo (MC) Method: Introduction, Metropolis algorithm, advanced algorithms for Monte Carlo simulations, comparison with Molecular Dynamics.

Module 4 (10 hours)

Mesoscopic Simulation Techniques:
Lattice Boltzmann Method (LBM): Boltzmann equation, derivation of the hydrodynamic equation from Boltzmann equation, Lattice Boltzmann equation and LBM, applications of LBM.
Dissipative Particle Dynamics (DPD): Fundamentals of DPD simulations, timestep size and noise, repulsion parameter, approximate expressions for transport coefficients.
Introduction to Multiscale methods and applications.

References:

1. Bird, G.A., Molecular Gas Dynamics and the Direct Simulation of Gas Flows, Oxford Science Publications, 1994
2. Goldstein, H., Poole, C., and Safko, J., Classical Mechanics, 3rd Edn., Pearson Education, 2006.
3. Bowley, R., and Sanches, M., Introductory Statistical Mechanics, 2nd Edn., Oxford Science Publications, 2007.
4. Ercolessi, F., A Molecular Dynamics Primer, Notes of Spring College in Computational Physics, ICTP, Trieste, June 1997 .
5. Liu, Wing Kam, Karpov, E.G., and Park, H.S., Nanomechanics and Materials, John Wiley & Sons, 2006.
6. Robert, K., Ian, H., Mark, G., Nanoscale Science and Technology, John Wiley & Sons, 200
7. Groot, R.D., and Warren, P.B., Dissipative particle dynamics: Bridging the Gap between Atomistic and Mesoscopic Simulation, J. Chem. Phys, 107, 4423 (1997).

ME6325 Finite Elements Method and Applications

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (12 Hrs.)
Introduction – Basic concepts – steps involved in finite element analysis – Variational methods of approximation – Galerkin's method – shape functions – Family of elements – Assembly and solution techniques – One dimensional problems.

Module 2 (10 Hrs.)
Analysis of scalar field problems and vector field problems – Finite element analysis of fluid mechanics and heat transfer problems – Heat conduction – Energy and Navier stokes
equations.

Module 3 (10 Hrs.)
Elasticity problems – Two and three dimensional elasticity problems – Bending of beams – The Euler – Bernoulli beam element, Plane stress and Euler – Bernoulli element – bending of elastic plate – classical plate model – Shear deformable plate model – Finite element.

Module 4 (10 Hrs.)
Eigen value and time dependent problems – Formulation of Eigen value problems – Time dependent problems – Applications – Non-linear problems – Finite element error analysis – Automatic mesh generation.

References :

1. J N Reddy, An introduction to the infinite element method – McGraw Hill book company
2. C Zienkiwiez, The finite element method - McGraw Hill Book company, New York
3. K H Huebner, The finite element method of engineers – John Wily & Sons, New York
4. L J Segerlind, Applied finite element analysis – John Willy & Sons, New York

NS6125 Carbon Nanotube Science and Technology

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (12 hours)
Introduction to Carbon-Nanotube Science and Technology-Synthesis-Defect Control- Mechanical and Thermal Properties-Electronic Structure and Atomic Arrangement–Transport Properties–Single and Double-Wall Carbon Nanotubes-Chemical Reactivity-Related Structures - Applications of Carbon Nanotubes – Electronics, energy, mechanical, sensors, field emission and lighting, biological – Environmental and health effects of carbon nanotubes
Metrology for CNT–electron microscopy–HRTEM-electron diffraction–SPM– Spectroscopy-Photoluminescence-Synthesis methods–Bulk production methods such as arc discharge and laser vaporization, chemical vapor deposition- purification by dry and wet method -sorting–organization into fibers–suspensions of CNTs–dry and wet spinning of CNT from liquid suspensions–direct spinning from CVD–organization on surfaces–organized assembly–field and flow directed growth–surface directed growth(epitaxy)–patterned growth on surfaces

Module 2 (12 hours)
Mechanical Properites and thermal stability of carbon nanotubes – ballistic heat transport – phonon transport – thermal conductance- length effect on thermal conductivity – influence of defects on thermal conductivity – diffusive heat transport in SWNTs – Heat transport in MWNTS
Introduction to optical response of Carbon Nanotubes – Excitonic effects – Optical spectra of SWNTs – pressure, temperature and strain effects – Overview of Resonance Raman Spectroscopy – Photoluminescence spectroscopy of nanotubes – photoluminescence imaging - Introduction to ultrafast sepectroscopy of carbon nanotubes - Rayleigh scattering spectroscopy – near field optical microscopy for carbon nanotube study and characterization.

Module 3 (10 hours)
Magnetic phenomena in carbon nanotubes – band structure – magnetization – magneto transport – magneto optics – Introduction to Carbon nanotube optolectronics- Overview of CNT electronics – Photoconductivity - Nanotube photodetectors – CNT photoconductor- Photovoltage in CNT diodes – photovoltage imaging – Electroluminescence- Electrical transport in Carbon Nanotubes – Quantum transport – Quantum dots

Module 4 (8 hours)
Recent advances – double wall carbon nanotubes – preparation – properties and applications – thermal, chemical and mechanical properties – Doped carbon nanotubes – methods, characterization and applications – electrochemistry of carbon nanotubes – introduction to inorganic nanotubes and fullerene like structures – Graphenes and their properties.

References:
1. 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.
2. Michael J. O'Connell, Carbon Nanotubes: Properties and Applications, CRC; 1 edition, 2006.
3. Peter J. F. Harris, Carbon Nanotubes and Related Structures, Cambridge University Press; 1st edition, 2002.

ME6511 Composite Materials: Mechanics, Manufacturing and Design

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (9 Hours)
Introduction: Classification of composite materials and geometric morphology, advanced metal, ceramic, and polymer matrix composites, reinforcing fibers, interfaces, manufacturing of composites.

Module 2 (11 Hours)
Behavior of unidirectional(UD) composites: review of the theory of elasticity, Hooke's law for generally anisotropic elastic solids, lamina stress-strain relationships, strength of UD composites, failure modes, short fiber composites, theories of stress transfer, analysis of orthotropic lamina, stress strain relationships, strengths.

Module 3 (12 Hours)
Analysis of laminated composites, stress-strain variation, synthesis of stiffness matrix, construction and properties of special laminates, determination of laminae stresses and strains, analysis of laminates after initial failure, ply-by-ply failure analysis of laminates, laminate analysis through computers, hygrothermal stresses, fatigue failure mechanisms, damage accumulation, methods of fatigue analysis and design, experimental characterization of composites, interlaminar stresses, fracture mechanics of fiber composites

Module 4 (10 Hours)
Introduction to composite structures; effective moduli and rigidities of compound laminates, properties of composite sections and stiffened panels, introduction to laminated beams, plates, and shells, introduction to composite structural design.

References:

1. B.D. Agarwal and L.J. Broutman, "Analysis and Performance of Fibre Composites", John Wiley & Sons Inc.
2. Ronald F. Gibson, "Principles of Composite Material Mechanics", McGraw Hill.
3. Stephen W Tsai, H. Thomas Hahn, "Introduction to Composite Materials", Technomic Publishing Company
4. R. M. Jones, "Mechanics of Composite Materials", McGraw-Hill.
5. D. Hull and T. W. Clyde, "An Introduction to Composite Materials", Cambridge University Press.
6. Mel M Schwartz, " Composite Materials Handbook", McGraw-Hill Inc.

NS6126 Combustion and Nanoparticle Fuel-additives

Prerequisite:- Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (10 hrs)
Review of basic thermodynamics and gaseous mixtures, Combustion Thermodynamics, Stoichiometry, First and Second Laws of Thermodynamics applied to combustion, Composition products in equilibrium.

Module 2 (10 hrs)
Fundamentals of combustion kinetics, General characteristics of combustion flame, detonation, deflagration, Factors affecting flame velocity and thickness, Quenching, Flammability, Flame stabilization, Laminar premixed flames, diffusion flames, Turbulent premixed flames.

Module 3 (10 hrs)
Combustion in I.C. engines, A/F ratio requirements, Ignition temperature- Ignition delay, Normal combustion in SI engines, Knocking, Effect of variable on knocking tendency, Octane number, Normal combustion in CI Engines- Theories of detonation - Cetane number

Module 4 (12 hrs)
Fuels for I.C. Engines, Properties of fuels, Measurement apparatus, Fuel additives, Nano fuel additives, Nano Catalysts, Nano fluids, Nano fluid preparation, Engine emissions, Effect of nano particles on fuel properties and emissions, Emission control devices

References

1. Stephen R Turns, An Introduction to Combustion, McGraw- Hill International Edition, 2000.
2. Kuo, K. K., Principles of Combustion, John Willey & Sons, 1986.
3. Mukunda, H. S., Understanding Combustion, Macmillan India Ltd., 1992.
4. Smith, M. L. and Stinson, K. W., Fuels and Combustion, McGraw-Hill, 1952.
5. Heywood, J. B., Internal Combustion Engine Fundamentals, McGraw-Hill, 1989.
6. Mathur, M. L. and Sharma, R. P., Internal Combustion Engines, Dhanpath Rai & Sons, 2005.
7. Fristrom. R. M. and Westenberg, A. A., "Flame Structure", McGraw – Hill Book Co. New York, 1965.
8. Maleev, M. L., Internal Combustion Engines, Second edition, McGraw-Hill, 1989.
9. Mathur, M. L. and Sharma, R. P., Internal Combustion Engines, Dhanpath Rai & Sons, 2005.
10. G. R. Pryling, "Combustion Engineering", Revised Edn., Combustion Engg. Inc., New York 1967.
11. C. Eckbreth, "Laser Diagnostics for Combustion Temperature and Species", Cambridge, Abacus Press, 1988.
12. Fristrom. R. M. and Westenberg, A. A., "Flame Structure", McGraw – Hill Book Co. New York, 1965.
13. M. W. Thring, "The Science of Flames and Furnace", Chapman & Hill Ltd., London 1962.

NS6127 Polymer Chemistry

L	T	P	C
3	0	0	3

Prerequisite:- Nil
Total Hours: 42

Module 1 (12 Hours)
Introduction to Polymers, Basic concepts, characteristic features, texture of polymers, molecular forces and chemical bonding, secondary bond forces, tacticity in polymers, stereo isomerism in polymers, basic determinants of polymer properties, polymer chain flexibility, factors affecting chain flexibility, glass transition temperature and crystalline melting points, variation and structure, molecular interpretation of glassy state of polymers.

Module 2 (10 Hours)
Compounding and processing of polymers, Additives for compounding plastics, additives for compounding of rubbers, two roll mill, banbury mixer, pigments, processing aids, processing methods for the manufacture of products, blending and mastication, masterbatching, mixing and compounding, calendaring, extrusion and moulding. Different elastomer curing systems-efficient, semi efficient, conventional and sulphurless curemechanism of vulcanization, sulphur vulcanization, non sulphur vulcanizing systems for olefin rubbers, batch vulcanization-autoclave, gas curing, oven curing, water curing, cold curing, continuous vulcanisation-high performance steam, hot air tunnel, molten salt bath, fluidized bed, continuous drum cure, microwave curing.

Module 3 (10 Hours)
Testing of Rubbers. Importance of standards and standards organizations, processability and performance, testing of plastics and rubbers, material characterization tests such as hardness, tensile stress/strain, compression stress/strain, shear stress/strain, flexuaral stress/strain, tear tests, rebound resilience, friction, creep, fatique, melt flow index, capillary rheometer test, viscosity test, gel permeation chromatography, thermal analysis such as TGA, TMA, and DSC.

Module 4 (10 Hours)
Introduction to polymer melt rheology, viscosity, types of fluid flow, time dependent fluids, time independent fluids, viscoelastic fluids, complex rheological fluids, Newtonian fluids, non-Newtonian fluids, Bingham plastics, psuedo plastics, rheopectic and thixotropic behaviour, rheological measurements-the capillary rheometer, cone and plate viscometer, melt flow index apparatus, elastic effects in polymer melt flow-die swell, elastic turbulance, melt fracture, sharkskin.

References

1. Fred W. Billimeyer, Jr, Text Book of Polymer Science, third edition, Wiley Interscience Publication, 1994.
2. Joel R. Fried,mPolymer Science and Technology, Prentice- Hall, Inc. Englewood Cliffs, N. J., USA, 2000.
3. Hand book of Elastomers: New Developments and Technology (Eds. A. K. Bhowmic and H. C. Stephense), Marcel- Dekker Inc., New York, 1995.
4. D. R. Paul and S. Newman, Polymer Blends, Academic Press, New York, 1978.
5. M. J. Folkes, Short Fibre Reinforced Thermoplastics, John Wiley, New York, 1982.
6. Jacob Kline, Handbook of Biomedical Engineering, Academic press, NY, 1988.
7. Joseph D. bronzino, The Biomedical engineering Handbook, CRC press, London, 2003.