Master of Technology (M.Tech.)

Nano-Science and Nano Technology

First Year - Semester – I

S.No.	Course Code	Course Title	L	T	P	C
1	NSNT - 101	Nano data Science & Nano data Analytics	3	0	0	3
2	NSNT - 102	Quantum Physics for Nanostructures	3	0	0	3
3	NSNT - 103	Applied Solid State Physics and Chemistry	3	0	0	3
4	NSNT - 104	Introduction to Nano Science and Nano Technology	3	0	0	3
5	NSNT - 105	Nanomaterial Characterization Techniques	3	0	0	3
6	NSNT – 106	Material Synthesis and Experiments	0	0	3	2
7	NSNT - 107	Seminar – I	0	0	1	1
		Total				18

First Year - Semester – II

S.No.	Course Code	Course Title	L	T	P	C
1	NSNT - 108	Mechanical processing and properties of Nanostructure Materials	3	0	0	3
2	NSNT - 109	Design and Synthesis of Nanomaterials	3	0	0	3
3	NSNT - xxx	Elective – I	3	0	0	3
4	NSNT - xxx	Elective - II	3	0	0	3
5	NSNT - xxx	Elective – III	3	0	0	3
6	NSNT – 110	Nano scale measurement and Analysis Laboratory	0	0	3	2
7	NSNT - 111	Seminar – II	0	0	1	1
		Total				18

Second Year - Semester – III

S.No.	Course Code	Course Title	L	T	P	C
1	NSNT – 201	Technical Communication, Research & IPR	1	0	2	2
3	NSNT - 202	Project – I				16
		Total				18

Second Year - Semester – IV

S.No.	Course Code	Course Title	L	T	P	C
1	NSNT - 203	Project – II				18
		Total				18

List of Elective Courses for II Semester

S.No.	Course Code	Course Title	L	T	P	C
1	NSNT - 501	Applied Nano Science (Nanoscale Devices)	3	0	0	3
2	NSNT - 502	Semiconductor devices & Nano-electronics	3	0	0	3
3	NSNT - 503	Thin Film Technology	3	0	0	3
4	NSNT - 504	MEMS, NEMS theory & devices	3	0	0	3
5	NSNT - 505	Environmental Nano Science Nano Technology	3	0	0	3
6	NSNT – 506	Computational Nano science & Nanotechnology	3	0	0	3
7	NSNT - 507	Nano Bioinformatics & Bioengineering	3	0	0	3
8	NSNT - 508	Nanoscopic Dielectric & Ferroelectric Phenomena	3	0	0	3
9	NSNT - 509	Carbon Nanomaterials and Nano Composites	3	0	0	3
10	NSNT – 510	Lithographic Techniques For Device Fabrication	3	0	0	3
11	NSNT - 511	Energy Technologies	3	0	0	3

Course Code: NSNT - 101 **Breakup: 3 –0 – 0 – 3**
Course Name: Nano Data Science & Nano Data Analytics

Object, Material, Perception & Reality, Subjective idealism and Vijnana-vada, Scientific Experiments What is Data? Nano Data, Nano Science & data science, Types of Data, Image representation, 3 Dimensional Data, Data Preprocessing & data Transformations, Descriptive & Predictive Data Mining.
Clustering algorithms, Distance method, and applications. Machine learning in Nano science, Categories of Machine learning, Algorithm learning, supervised learning, K -nearest neighbours, decision tree, nave bays, logistic regression, support vector machine, Artificial Neural Network. Introduction to AI, Concept of AI techniques, Artificial Intelligence & Nano Technology.
Computational Material science, computer-aided design or processing. Application of computer technology in advanced material science and processing, Material science database, Biomat _dBase-a database on Biomaterials, cBiT: A transcriptomics database for innovative biomaterial, The Database of Experimental Biomaterials and their Biological Effect (DEBBIE), OMDB, COD, PDB. CSD databases. Nanomaterials Databases Data Sources for Promoting Design and Risk Assessment of Nanomaterials:Nano Werk, SatatNano; SAPdb: A database of nanostructures formed by self-assembly of short peptides.

Data Science for nano image analysis, Role of Bioinformatics in Nanotechnology: Nanoinformatics – Biomedical Informatics, understanding of microarray data, normalizing microarray data, , Bio-nano-informatics. Biomedical Big Data Analytics, Bioinformatics, Imaging & Informatics, image processing, shape analysis, Lattice pattern analysis, Health Informatics.

Data Analytics using RapidMiner /Basic programming in PYTHON and/or MATLAB using simple examples.

Reference Books:
Louis Theodore, Nanotechnology: Basic Calculations for Engineers and Scientists, Wiley (2005)
Amos Gilat, MATLAB: An Introduction with Applications (4th Ed), Wiley
Rudra Pratap, Getting Started With MATLAB: A Quick Introduction for Scientists and Engineers, OUP (2016)
Ikeda, Susumu, Kotani, Motoko, A New Direction in Mathematics for Materials Science, Springer (2015)

Course Code: NSNT - 102 **Breakup: 3 –0 – 0 – 3**
Course Name: Quantum Physics for Nanostructures

Importance of Quantum theory, Wave-particles duality, de-Broglie and Fermi Wavelengths, Wave function, Dynamical operators, Uncertainty principle, Quantum numbers and Hydrogen atom problem, Pauli exclusion principle. Schrodinger time dependent and time independent wave equations - analytical solutions. One-Dimensional Potential well, Particle in 1D, 2D and 3D box, Rectangular Barrier, Concept of Tunneling, Reflectance, transmittance and tunnelling probability, Scanning tunnelling microscope

Description of the theory of Conduction in Solids -Drude model, Nearly free electron model, Dispersion relation for electron. Periodic lattice, Brillouine zones, Periodic potential, Bloch Theorem, Kronig-Penny Potential and Electronic energy bands, direct and indirect gap semiconductors. Concept of Quantum Confinement, Quantum Dots, Quantum Well and Quantum Wires, Density of states in 3D, 2D, 1D and 0D solid, carrier concentration.

Time-dependent change in potential, First-order time-dependent perturbation, Fermi's golden rule, Photon emission due to electronic transitions, Fermi's golden rule for stimulated optical transitions, Semiconductor laser.

Reference Books:

A. F. J. Levi, Applied Quantum Mechanics, Second edition, Cambridge University Press, 2006.

Richard L. Liboff, Introductory Quantum Mechanics, Fourth edition, Pearson Education Inc, India, 2003.

Robert Eisberg and Robert Resnick, Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, second Edition, John Wiley & Sons, Canada, 1985.

A. Ghatak and S. Lokanathan, Quantum Mechanics–Theory & Applications, Macmillan India Limited, New Delhi, 2002.

A. Beiser, Concepts of Modern Physics, Sixth edition, TataMcGraw- Hill Edition, New Delhi, 2003.

Course Code: NSNT - 103 **Breakup: 3 –0 – 0 – 3**
Course Name: Applied Solid State Physics and Chemistry

Fundamentals of materials science and materials chemistry. bonding, crystal structure, defects, diffusion, phases, as well as the electrical, thermal, optical, magnetic, and chemical properties of metals, ceramics, and nanomaterials. atomic bonding and crystal structure impact the properties of bulk solids, consideration will also be given to the impact of Quantization effects on nanomaterial properties. Structure of solids, symmetry concepts, crystal structure. Preparative methods and characterization of inorganic solids. Crystal defects and non-stoichiometry. Interpretation of phase diagrams, phase transitions. Kinetics of phase transformations, structure property correlations in ceramics, glasses, polymers. Composites and nanomaterials.
Development of advanced fabrication techniques, Synthesis of materials and structures that exhibit reduced dimensionality, control quantum size effects in a variety of materials. semiconductor quantum wells, quantum dots and heterojunctions, electrical, optical and magnetic properties of reduced-dimensional materials and nanostructures, modern nanotechnology.

Reference Books:
Anthony R. West., Solid State Chemistry and its Applications, Wiley, 1998
Stephen Elliott, The Physics and Chemistry of Solids, John Wiley, 1998
William D. Callister, Materials Science and Engineering: An Introduction, (9th Ed), Wiley (2013)
Hull, D and Bacon, D.J., Introduction to Dislocations, Butterworth-Heinemann, 2001
David A. Porter, Phase Transformations in Metals and Alloys, (3rd Ed) (Revised Reprint), CRC Press
Neil W. Ashcroft, and David Mermin N., Solid State Physics, Brooks/Cole
S. M Lindsay, Introduction to Nanoscience, Oxford (2010)
Charles Kittel., Introduction to Solid State Physics, John Wiley and Sons
Claude Cohen-Tannoudji, Bernard Diu, Frank Laloe. Quantum Mechanics (2 vol. set), John Wiley & Sons

Course Code: NSNT - 104 **Breakup: 3 –0 – 0 – 3**
Course Name: Introduction to Nano Science and Nano Technology

Introduction to Nano Science and Nano Technology, Nanofabrication Technology: Top down - Physical methods- Inert gas condensation, aerosol method, Arc discharge, RF-plasma, Plasma arc technique, laser ablation, Gas-phase synthesis, Spray Pyrolysis, Ball Milling, Combustion. Bottom up - Chemical Methods - Zero dimensional, one dimensional and two dimensional nanostructures, Nucleation theory, Homogeneous and heterogeneous nucleation, Metal nanocrystals by reduction, Solvothermal/Hydrothermal synthesis, Photochemical synthesis, Electrochemical synthesis, Thermolysis routes, Sonochemical routes, Hybrid methods, Sol- gel, Micelles and microemulsions, Bio-Synthesis.

The interdisciplinary nature of nanotechnology and nanoscience (including areas of physics, chemistry, material science and others), nanoscience phenomena (the crossover from bulk to quantum mechanical properties), and applications (from integrated circuits, quantum computing, MEMS, Nano-magnetics and bioengineering). Introduction to advanced optics such as LASERS, plasmonics, biophotonics, nanophotonics, non-linear optics etc.

Reference Books:

Guozhong Cao. Ed Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, World Scientific Series in Nanoscience and Nanotechnology, 2011.
G.A. Ozin and A.C. Arsenault, Nanochemistry: A chemical approach to nanomaterials, Royal Society of Chemistry, 2009.
S. M Lindsay, Introduction to Nanoscience, Oxford (2010)
Charles P. Poole Jr. & Frank J. Owens, Introduction to Nanotechnology, Wiley (2003)
M.S. Ramachandra Rao, Nanoscience and Nanotechnology: Fundamentals of Frontiers, Wiley
M.A. Shah, Nanotechnology: The Science of Small, Wiley (2013)
Cao G., Nanostructures and Nanomaterials, Synthesis Properties and Applications, Imperial College Press, 2004

Course Code: NSNT - 105 **Breakup: 3 –0 – 0 – 3**
Course Name: Nanomaterial Characterization Techniques

Concepts of Metrology- Accuracy, precision and reliability; Types of Errors - Systematic Errors and Random Errors, Statistical analysis of errors.
Optical microscopy; Electron microscopy- Scanning Electron Microscopy, EDX, WDX; Transmission Electron Microscopy; EELS; SPM.
UV-Vis Spectroscopy; Ellipsometer; XPS; XAS; XRD; Raman Spectroscopy - Surface-enhanced Raman Spectroscopy.
Basic design of Scanning Probe Microscopes; Scanning Tunneling Microscope: Principles of operation, Quantum Mechanical Tunneling phenomenon in STM, Different modes of operation; STS - Principles of operation, applications.
Atomic Force Microscope - Modes of operation of AFM, Advanced Modes of AFM - Force Modulation, Conductive AFM, EFM, MFM, SCM.
Principles of operation, Different modes of operation, Spectroscopic Applications of NSOM.
Principles, Components of SQUID systems, Vibrating Sample Magnetometer (VSM), Advanced Topics

Reference Books:
R.W. Cahn, E.M. Lifshitz, Concise Encyclopedia of Materials Characterization: Advances in Materials Sciences and Engineering,Elsevier, 2016.
Yang Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods,John Wiley & Sons, 2013.
Richard Leach, Fundamental Principles of Engineering Nanometrology, Elsevier, 2014.
Mauro Sardela, Practical Materials Characterization, Springer, 2014.
Ewen Smith, Geoffrey Dent, Modern Raman Spectroscopy: A Practical Approach, John Wiley & Sons, 2013.
Nikodem Tomczak, Kuan Eng Johnson Goh, Scanning Probe Microscopy, World Scientific, 2011.
Sam Zhang, Lin Li, Ashok Kumar, Materials Characterization Techniques, CRC Press, 2008.

Course Code: NSNT - 108 **Breakup: 3 –0 – 0 – 3**
Course Name: Mechanical Processing and Properties of Nanostructure Materials

Processing of metals and alloys: rolling, forging, extrusion, wire drawing, sheet metal forming.
Processing of polymers: injection moulding, thermoforming, vacuum and pressure assisted forming.
Processing of powders of metals and ceramics: Selection and characterization of powders, compacting and sintering; mechanical working.
Production of Porous and Dense Composite Components: Metal- polymer- and ceramic- based composites.
Processing of structural and functional nanocrystalline materials: Properties required of nanocrystalline materials used for structural, hydrogen storage, magnetic and catalytic applications; processing techniques; techniques for retaining the nanocrystalline structure in service.
Microstructure and properties: Properties slightly dependent on temperature and grain size; properties strongly dependent on temperature and grain size; strengthening mechanisms; enhancement of available plasticity; grain size evolution and grain size control; Hall-Petch relation, microstructure – dislocation interactions at low and high temperatures; effects of diffusion on strength and flow of materials; methods of enhancing or retarding diffusion; grain boundary sliding and grain boundary migration; current limitations on approaches based on dislocation theory; possibilities for predictive design.

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

Course Code: NSNT - 109 **Breakup: 3 –0 – 0 – 3**
Course Name: Design and Synthesis of Nanomaterials

Chemical Routes for Synthesis of Nanomaterials: Chemical precipitation and co-precipitation; Sol-gel synthesis; Microemulsions or reverse micelles; Solvothermal synthesis; Thermolysis routes, Microwave heating synthesis;
Sonochemical synthesis; Photochemical synthesis; Synthesis in supercritical fluids.
Metal Nanoparticles: Size and shape control of metal Nanoparticles and their characterization; Study of their properties: Optical, electronic, magnetic; Surface plasmon band and its application; Role in catalysis, Alloy
Nanoparticles,
Semiconductor Nanoparticles: Size and shape control of semiconductor Nanoparticles and their characterization; Study of their properties: optical and electronic and its application; Synthesis and application of Core-Shell
structured semicoductor nanoparticles (Type I and Type II).
Organic nanoparticles: Size and shape control of nanoparticles and their characterization; inorganic-organic hybrid nanoparticles; Nanopolymers: Preparation and characterization of diblock Copolymer based nanocomposites; Applications of Nanopolymers in Catalysis
Top-down techniques: photolithography, other optical lithography (EUV, X-Ray, LIL), particle-beam lithographies (e-beam, FIB, shadow mask evaporation), scanning probe lithographies.

Reference Books:

Nanochemistry: A Chemical Approach to Nanomaterials, Geoffrey A. Ozin, Andre C. Arsenault, Royal Society of Chemistry, Cambridge, UK, 2005.
Chemistry of nanomaterials : Synthesis, properties and applications C. N. R. Rao, Achim Muller, A. K Cheetham, Wiely-VCH, 2004
Metal Nanoparticles: Synthesis Characterization & Applications, Daniel L. Fedlheim, Colby A. Foss, Marcel Dekker, 2002
Nanostructures and Nanomaterials - Synthesis, Properties and Applications - Cao, Guozhong, ying Wang, World Scientific, 2011

Elective Courses for II Semester

Course Code: NSNT - 501 **Breakup: 3 –0 – 0 – 3**
Course Name: Applied Nano Science (Nanoscale Devices)

Challenges in Nanoscience & Nanotechnology, Quantum mechanical, Physical and Biological aspects of Nanoscience & Technology, Nanodefects, Nanolayers and Nanostructuring, Growth and Fabrication of Nanostructures, Electron transport in nanostructures, Nanostructured electronic devices, Nano tunneling devices, Self organization phenomena at nanocrystal surfaces, Engineering of complex nanostructures, Quantum dot
nanostructures for single electron devices, Carbon nanotubes and carbon electronics, Quantum electronic devices (QEDs), Organic electronics, Complex integrated systems and information processing at nanoscale, Limits of integrated systems and nanodevices, Concept of heterostructure devices (e.g.; oxide heterostructures, photovoltaics, sensors, actuators, quantum dot heterostructure lasers etc.), Nano-MEMS, Introduction to quantum computation and soft computing.

Reference Books:
Nanoscience and Nanotechnology in Engineering, V. K. Vardan et. al., World Scientific, 2010.
Introduction to Nanotechnology & Nanoelectronics: Materials, Devices and Measurement Techniques, W. R. Fahrner, Springer, 2005.
Introduction to Nanoelectronics : Science, Technology, Engineering & Applications, V. V. Mitin, V. A. Kochelap, M. A. Satroscio, Cambridge University Press, 2008.
Nanoelectronics and Nanosystems, K. Goser, P. Glosekotter, J. Dienstuhi, Springer, 2005.
Nanostructures, V. A. Shchukin, N. N. Ledentsov, D. Bimberg, Springer, 2007.
Semiconductor LASERS I & II: Fundamentals, E. Kapon, Academic Press (Indian edition), 2006.
Optical Materials, John H. Simmons and Kelly S. Potter, Academic Press (Indian edition), 2006.
Electronic Properties of Materials, Rolf E. Hummel, Springer (3rd edition)
Energy Storage, R. A. Huggins, Springer, 2010.
Fundamentals of Photovoltaic Modules and their Applications, G. N. Tiwari, S. Dubey & Julian C. R. Hunt, RSC Energy Series, 2009.

Course Code: NSNT - 502 **Breakup: 3 –0 – 0 – 3**
Course Name: Semiconductor Devices & Nano-electronics

Non idealities in MOS structure, High-k dielectrics, Metal gate electrodes and work function engineering, C-V and I-V characteristics Nano MOSFET performance metrics, non-classical transistor structure: Transport in Nano MOSFET, velocity saturation and overshoot, ballistic transport, Silicon on Insulator (SOI) –PDSOI and FDSOI, Multi gate FET, metal-semiconductor source/drain junctions, Germanium Nano MOSFETs, Effect of strain and quantization on transistor performance Compound semiconductor MESFETs and MOSFETs, Hetero structure MOSFETs, Emerging Research Devices and architectures, Characteristics of nano materials; scaling of properties with particle size; quantum confinement; device concepts based on nanomaterials and nanostructures; some methods for the preparation and characterization of nanomaterials and structures.

Reference books

Taur and Ning, Fundamentals of Modern VLSI Devices, Cambridge University Press
Streetman and Banerjee, Solid State Electronic Devices, Prentice Hall
Achutan and Bhat, Fundamentals of Electronic Devices, McGraw Hill
E.H. Nicollian and J.R.Brews, MOS (Metal Oxide Semiconductor) Physics and Technology, Wiley Publishers

Course Code: NSNT - 503 **Breakup: 3 –0 – 0 – 3**
Course Name: Thin Film Technology

Introduction to thin films, Technology as a drive and vice versa; Structure, defects, thermodynamics of materials, mechanical kinetics and nucleation; grain growth and thin film morphology; Basics of Vacuum Science and
Technology, Kinetic theory of gases; gas transport and pumping; vacuum pumps and systems; vacuum gauges; oil free pumping; aspects of chamber design from thin film growth perspectives; various Thin film growth techniques
with examples and limitations; Spin and dip coating; Langmuir Blodgett technique; Metal organic chemical vapour deposition; Electron Beam Deposition; Pulsed Laser deposition; DC, RF and Reactive Sputtering; Molecular beam epitaxy; Characterization of Thin films and surfaces; Thin Film processing from Devices and other applications
perspective.

Reference Books:
Materials Science of Thin Films Deposition and Structure, Milton Ohring.
Thin Film Solar Cells, Chopra and Das
Thin Film Deposition: Principles and Practice, Donald Smith.
Handbook of Thin Film Deposition (Materials and Processing Technology), Krishna Seshan.
Handbook of Physical Vapor Deposition, D. M. Mattox.

Course Code: NSNT - 504 **Breakup: 3 –0 – 0 – 3**
Course Name: MEMS, NEMS Theory & Devices
Mechanical phenomena at the micro and nano scales. Basics of continuumtheory, continuum hypothesis, elasticity, thermoelasticity, fluid mechanics, heat conduction,electromagnetism, coupled thermalelastic
and electrostatic-elastic systems, MEMS and NEMSstructures -- beams, plates, and membranes, scaling of mechanical properties and continuumlimits, numerical methods for mechanical modelling, mechanics beyond continuum theory. Micro- and Nano Fluidics.

Reference Books:
John A. Palesko and David H. Bernstein, Modeling MEMS and NEMS, Chapman and Hall/CRC
Leondes, Cornelius T. (Ed.), Mems/Nems: (1) Handbook Techniques and Applications Design Methods, (2) Fabrication Techniques,
(3) Manufacturing Methods, (4) Sensors and Actuators, (5) Medical Applications and MOEMS, Springer (2006)
Tai-Ran Hsu, MEMS & MICRO SYSTEMS Design and Manufacture, Tata McGraw Hill, New Delhi,2002
Vijay K. Varadan, K. J. Vinoy, S. Gopalakrishnan, Smart Material Systems and MEMS: Design and Development Methodologies,
Wiley (2006)

Course Code: NSNT - 505 **Breakup: 3 –0 – 0 – 3**
Course Name: Environmental Nano Science Nano Technology

Properties and composition of nanomaterials and characteristics of nanotechnologies and their effects towards industrial applications. The principles of nanocatalysis, membranes, nanofiltration and other methods in the processes of water treatment processes will be introduced and studied. The basics of nanoparticle aerosol formation in industrial processes will be assimilated. Nanofiltration and nanocatalysiswill be discussed for the application of air pollution abatement. The applications of nanotechnologies in waste treatment and polluted site remediation will be reviewed. The impact of nanomaterials to the environment and human health.

Reference Books:
Sridharan, Karthiyayini (Ed.), Emerging Trends of Nanotechnology in Environment and Sustainability: A Review-Based Approach, Springer (2018)
ChaudheryMustansar Hussain, Ajay Kumar Mishra, Nanotechnology in Environmental Science, 2 Volumes, Wiley (2018)
Rai, Mahendra, da Silva, Silvio Silvério (Eds.), Nanotechnology for Bioenergy and Biofuel Production, Springer (2017)
M. H. Fulekar, Bhawana Pathak, Environmental Nanotechnology, CRC Press (2018)
Kaufui V. Wong, Nanotechnology and Energy, CRC Press (2018)

Course Code: NSNT - 506 **Breakup: 3 –0 – 0 – 3**
Course Name: Computational Nano-Science and Nano-Technology

Basics of Nano-science and technology understanding: energetics, materials structure and symmetry, materials response to applied fields, mechanics and physics of solids and soft materials, Computer modelling to understand and predict materials properties such as stability and reactivity. This can be also used to optimization of materials processing routes, computer-aided modelling. and systems modelling; Fourier analysis.

Computational Nano-Science and Nano-Technology Advances in Nanoscience and Nanotechnology, Role of ICT, Computational Physics of Nanostuructures, Computer simulation methods: Minimization, Molecular dynamics, Monte Carlo Simulations, Simulated Annealing. Basic concepts of simulation- data manipulation, properties and processing of materials-Three-dimensional model for capillary nanobridges and capillary forces. Molecular dynamics simulation.
Phase Space; Conformational Search and Conformational Analysis, Understanding of iterations, convergence, protocols and algorithm such as steepest descents, conjugate gradient etc.,
Molecular Dynamics;
Basics of Monte Carlo Methods; Computations of Phase Transition; General Basis for predicting physical properties of nanocrystals and large clusters; Quantum Confined Systems & computational techniques, Monte Carlo simulation-Applications to systems of classical particles-modified -percolation system-variation Monte Carlo method
Computational Electrodynamics Methods; Large Scale Electronic Transport Calculations;
Density Functional Calculations in Carbon Nanotubes; Time Dependent Density Functional Theory;
Computational Study of Nanotubes; Excited State Properties (GW, BSE); Computing Mechanical Properties and Modeling Growth.
Molecular Simulation using MDWeb/GROMACS. LAMMPS

Reference Books:
S.C. Chapra and R.P.Canale, “Numerical methods for Engineers”, Tata McGraw Hill,
New Delhi, 2002.
Erwin Kreyzig, “Advanced Engineering Mathematics”, John Wiley & Sons, 2004.
R.J. Schilling and S.L. Harris, “Applied Numerical Methods for Engineers using MATLAB and C”, Thomson publishers, New Delhi, 2004..
D. Frenkel and B. Smith, “Understanding molecular simulation from algorithm to applications”, Kluwar Academic Press, 1999.
K. Ohno, K. Esfarjani and Y. Kawazoe, “Introduction to Computational Materials Science from ab initio to Monte Carlo Methods”, Springer-Verlag, 1999.

Course Code: NSNT - 507 **Breakup: 3 –0 – 0 – 3**
Course Name: Nano-Bioinformatics & Bioengineering

Nano-Informatics, BioNanoinformatics,An Integrated Information Management System for Personalized Oncology. Computer Aided Drug Delivery. Bioinformatics: Concepts, Methodologies, Tools, and Applications, Nanoinformatics: a new area of research in nanomedicine. Bioinformatics; Enzyme Informatics & Vaccine Design; Homology Modelling; Genomics & Proteomics;
Bionanoinformatics for minimally-invasive image-guided surgery; critical care informatics in ICU for real-time evidence-based decision making, Telemedicine, pathological imaging informatics to assist clinical diagnosis, critical and chronic care health informatics for evidence-based decision, Nanomanufacturing and Characterization Modalities for Bio-Nano-Informatics Systems. Bionanoinformatics.
What is microarray, understanding of microarray data, normalizing microarray data, detecting differential gene expression, correlation of gene expression data to biological process; Expression matrix, Normalisation, Clustering algorithms, Distance method, and applications. Bioconductors for short read analysis. Gene Expression Omnibus (GEO), ArrayExpress, SAGE databases,
Nanotechnology applications in Bioengineering, Tissue Engineering & Regenerative Medicine, Molecular engineering, nucleic acid self-assembly, nanomaterials, nanomedicne, and targeted imaging and delivery.

NanoBioengineering: Biocompatibility, Biomaterial's implantation, Evaluation of biomaterials, Nanobiomaterials, Biomaterials for imaging and diagnosis, Cell-Biomaterials interaction, Biomaterial and tissue engineering. Biomaterials: Design and Applications, Biomaterials for drug delivery application (small molecules, gene and protein). Genetic Engineering, Dynamic Systems Modelling (e.g. molecular pathway dynamics, cellular/tissue dynamics. Micro- and Nanofluidic technologies.

Applications of Bio/Nanoinformatics approach. Prediction of corona content using NP and protein descriptors: Sequence descriptors (PepStat), 3D structures Modelling.Vaccine designing, Bio-Nanoinformatics; Computer Aided Drug Design; Computational prediction of physico chemical properties, Dynamic Systems Modelling, Smart NanoTox.

Course Code: NSNT - 508 **Breakup: 3 –0 – 0 – 3**
Course Name: Nanoscopic Dielectric & Ferroelectric Phenomena

Introductory remarks on classical concepts of electrostatics and Maxwell e.m. field equations; Concept of dielectric constant for nanostructures; Quantum approach for carriers in dielectrics; Electric polarization and relaxation – frequency and temperature dependence; Optical properties and radiative process in dielectric heterostructures & nanostructures; Photoemission, Luminescence, Photoconduction, Quantum yield and quantum efficiency; Transport in nanostructure networks (e.g.; tunneling, hopping, coulomb blockade etc.), Transitions between electrical conductivity, Transient phenomena, Charge carrier injection from electrical contacts; Role of defects and impurities in transport properties; Dielectric properties of metals, semiconductors and insulators (with examples of polymer, ceramics and composites).
Spontaneous polarization and origin of Ferroelectricity; Phenomenology of Ferro, Antiferro, Pyro and Piezoelectric effects; Ferroelectric memory and its application for high density data storage; Charging of a dielectric nanostructure and mechanism of charge storage in it; Electrets and their applications; Ferroelectric-insulatorsemiconductor junctions;
Non-radiative and relaxation processes – multi-phonon capture at point defects, hot carrier relaxation; Electrooptic processes – Electro-optic, Photo-refractive and Magneto-optic effects; Elementary idea of Magneto-dielectric effect and Multiferroicity, Magnetoelectricity and Magnetoelectric coupling; Applications of multiferroicity and magnetoelectricity; Dielectric breakdown phenomena.

Reference Books:
Nanostructures: Theory & Modelling; C. Delerue, M. Lannoo, Springer, 2004.
Dielectric Phenomena in Solids, k. C. Kao, Academic Press, 2004
Broadband Dielectric Spectroscopy, F. Kremer and F. Nicholas. Springer, 2003.
Ferroelectric Devices, K. Uchino, Marcel Dekker, 2000.
Ferroelectric Thin Films, M. Okayama & Y. Ishibashi (eds.), Springer, 2004.
Handbook of Advanced Electronic and Photonic Materials and Devices:
Ferroelectrics & Dielectrics, Vol.4,
H. S. Nalwa (ed.), Academic Press, 2001.
Handbook of Advanced Electronic and Photonic Materials and Devices: Nonlinear Optical Materials, Vol. 9,
H. S. Nalwa (ed.), Academic Press, 2001.
Encyclopedia of Nanoscience & Nanotechnology, Vol. 5, H. S. Nalwa (ed.),
American Scientific Publishers, 2004.

Course Code: NSNT – 509 **Breakup: 3 –0 – 0 – 3**
Course Name: Carbon Nanomaterials and Nano Composites

Introduction to Carbon Nanomaterials, Carbon allotropes and their bonding between carbon atoms.
Structure, Synthesis, Functionalization of fullerenes, Applications – Solar Cells, Hydrogen storage, Bio-applications.
Types ; Structure; Properties- Electrical, Optical, Mechanical, Vibrational properties; Nanotube synthesis - carbon arc discharge, Laser ablation, Chemical Vapor Deposition, High-pressure CO process, Purification techniques of carbon nanotube. Functionalization- Covalent, non-covalent, and biological; Applications - Energy storage: Batteries, Fuel Cells: H2, Li storage, supercapacitors; Molecular electronics–Field emitting devices and Transistors, drug delivery, CNT based microscopy, Nanotube sensors.
Electronic band structure, Properties of Graphene: chemical, mechanical, electronic and thermal. Synthesis of Graphene – Exfoliation, Epitaxial, CVD, Hummer Method; Graphene Nanoribbon-
Functionalization- Covalent, non-covalent Application of Graphene; Applications – Graphene MOSFET – Opening a Band gap, Spintronics, Solar cells, gas sensors, supercapacitors.
Carbon Nanocomposite, Nanocones, Nanofibers, Nanodiscs and Nanodiamonds.

Reference Books:
Peter. J.F Harris, Carbon Nanotube Science: Synthesis, Properties and Applications, Cambridge University Press, 2011
Jamie H. Warner, Franziska Schaffel, Mark Rummeli, Alicja Bachmatiuk, Graphene: Fundamentals and Emergent Applications, Elseiver, 2013
Zhong Lin Wang, Nanowires and Nanobelts- Materials, Properties and Devices, Springer, 2006
Thomas Webbester, Carbon Nanotube preparation and properties, CRC Press, 1997
R Saito, G Dresselhaus, M S Dresselhaus, Physical Properties of Carbon Nanotubes, Imperial college press, 2004
Yury Gogotsi, Volker Presser, Carbon nanomaterials, CRC Press, 2014
CNR Rao and A Govindaraj, Nanotubes and Nanowires, RCS Nanoscience and Nanotechnology series, 2011
Michael J. O'Connell, Carbon Nanotubes: Properties and Applications, CRC Taylor and Franci group, 2006.
Mikhail I. Katsnelson, Graphene: Carbon in two dimensions, Cambridge University Press, 2012
Fernando Langa, Jean-Francois Nierengarten, Fullerenes: Principles and Applications , RSC Publishing, 2007

Course Code: NSNT - 510 **Breakup: 3 –0 – 0 – 3**
Course Name: Lithographic Techniques for Device Fabrication

Process steps involved in the optical lithography; Types - Contact, proximity printing and Projection Printing; Resolution Enhancement techniques for projection systems; Deep Ultraviolet lithography; Extreme Ultraviolet lithography; Scanning Near Field Optical Lithography.
Interaction of the electrons with the substrate; Electron Lithography System components; Raster scans and Vector scans; Electron resists and processing technique; Application of Electron Beam Lithography.
X-ray lithography system components, Resolution enhancement, X-ray mask construction, X-ray sources, x-ray resists.
Ion lithography system components; Focused Ion Beam Lithography; Masked Ion Beam Lithography; Ion Projection Lithography.
Scratching Lithography; Anodic Oxidation- Mechanism of Nano-oxidation; Dip-Pen Nanolithography - Mechanism, DPN Types: Parallel DPN, Polymer DPN, Application of DPN; Nano-shaving.
Micro-contact printing, Solvent-Assisted Micromoulding, Micromoulding in capillaries, Patterning SAMs.
Principle of Plasmonic Lithography, Plasmonic Mask, Near-field Plasmonic Lithography, Plasmonic Contact Lithography, Plasmonic direct write lithography.

Reference Books:
M Feldman, Nanolithography: The Art of Fabricating Nanoelectronic and Nanophotonic Devices and Systems, Woodhead Publishing, 2014.
Stefano Cabrini, Satoshi Kawata, Nanofabrication Handbook, CRC Press, 2012.
Bruce W. Smith, Kazuaki Suzuki, Microlithography: Science and Technology, Second Edition, CRC Press, 2007.
D Bucknall, Nanolithography and Patterning Techniques in Microelectronics, Elsevier, 2005.
Marc J. Madou, Manufacturing Techniques for Microfabrication and Nanotechnology, 3rd Edition, Vol II, CRC Press, 2011.
Mark J. Jackson, Micro and Nanomanufacturing, Springer Science & Business Media, 2007.
Ampere A. Tseng, Tip-Based Nanofabrication: Fundamentals and Applications, Springer Science & Business Media, 2011.
Hyongsok T. Soh, Kathryn Wilder Guarini, Calvin F. Quate, Scanning Probe Lithography, Springer Science & Business Media, 2013.

Course Code: NSNT - 511 **Breakup: 3 –0 – 0 – 3**
Course Name: Energy Technologies

Basics and Types of Renewable energy sources.
Energy Harvesting Sources, Types and mechanism – Solar, Thermoelectric, Piezoelectric; Electro dynamical and Biological; Energy harvesting devices and applications. Nanomaterials for energy harvesting.
Energy conversion – Types and mechanism; Electrochemical energy conversion, thermodynamics; Hydrogen Technology; Fuel Cells - fundamentals, classifications, Operating principles and design considerations, thermodynamics and kinetics of fuel cell process, performance evaluation of fuel cell, Fuel cell applications. Nanomaterials as electrode materials for fuel cells.
Solar energy: Photovoltaic fundamentals, Solar cell technologies, Types – Dye sensitized, Quantum dot, Copper indium gallium selenide (CIGS), Hybrid, Organic and Plasmonic solar cells etc,. Performance and parameter analysis of solar cells. Nanomaterials and Nanostructures for photovoltaics.
Photothermal systems: Types and performance of solar collectors - Flat Plate, Hot Air, Evacuated Tube, Parabolic, Compound Parabolic and Fresnel Solar Concentrators, Thermal Analysis and performance of Solar Collectors, Current and future scope of solar energy.
Electrochemical energy storage systems: Supercapacitors - Differences between capacitors, supercapacitors and batteries, classifications of supercapacitors. Batteries: Primary, Secondary, Lithium, Solid-state and molten solvent batteries; Lead acid batteries; Nickel Cadmium Batteries; Sodium ion and Aluminum Batteries. Nanostructured and Hybrid materials as electrodes for batteries and capacitors.
Magnetic energy storage systems (SMES); Thermal energy storage systems - Thermal energy storage materials – Types, thermo physical properties, Phase change materials for heating and cooling applications. Heat transfer fluids – Properties and mechanism.

Reference Books:
Chetan Singh Solanki, Solar Photovoltatics – Fundamentals, Technologies and Applications, PHI Learning Private limited, 2011
Ru-shiliu, Leizhang, Xueliang sun, Electrochemical technologies for energy storage and conversion, Wiley publications, 2012
Caye M. Drapcho, Nghiem Phu Nhuan and Terry H. Walker, Biofuels Engineering, McGraw-Hill Companies, 2008
Viswanathan, B and M Aulice Scibioh, Fuel Cells – Principles and Applications, Universities Press ,2006
Schaeffer, John, Real Goods Solar Living Sourcebook: The Complete Guide to Renewable Energy Technologies and Sustainable Living, Gaiam,2007
Frank Kreith and D.Yogi Goswami, Handbook of Energy Efficiency and Renewable Energy, CRC Press, 2007
John Twidell and Tony Weir, Renewable Energy Resources, Taylor & Francis, USA, 2006

Course Code: NSNT - 201 **Breakup: 1 –0 – 2 – 2**
Course Name: Technical Communication, Research & IPR

Critical reasoning and verbal deduction. Numerical Ability: Numerical computation, numerical estimation, numerical reasoning and data interpretation.
Basics of Technical Communication: Technical Communication: features; Distinction between General and Technical communication; Constituents of Technical Written Communication: Technical Terms; Paragraph-Text Readings, Mechanics of writing, Forms of Technical Communication: Letters. Reports: Types; Significance; Structure, Style & Writing of Reports and Proposal; Significance.
Presentation Strategies: Defining Purpose; Audience & Locale; Organizing Contents; Preparing, Outline, Seminar, workshop and Conference.
Research, Methods of Scientific research, Format of Project Report, Thesis, Research Article, Review Article, Searching in bibliographic databases
Ethics and Technology: Intellectual property rights, patenting, Entrepreneurship development, Risk Assessment and Management Information Security. IPR issues in Nano Science and Nano Technology, impacts of IT on language & culture localization issues – Unicode – IT and regional languages, Integrated Practice Management Systems, Various IPR laws Copyright and Patents.

Reference Books:
Improve Your Writing ed. V.N. Arora and Laxmi Chandra, Oxford Univ. Press, New Delhi.
Technical Communication – Principles and Practices by Meenakshi Raman & Sangeeta Sharma, Oxford Univ. Press 2007, New Delhi.
Effective Technical Communication by Barun K. Mitra, Oxford Univ. Press, 2006, New Delhi
Developing Communication Skills by Krishna Mohan, Meera Banerji- Macmillan India Ltd. Delhi.
Manual of Practical Communication by L.U.B. Pandey & R.P. Singh; A.I.T.B.S. Publications India Ltd.; Krishan Nagar, Delhi.
The Language of Literature and Science by A.Huxley
Core refere1. AnithaRao and BhanejiRao, “Intellectual Property rights: A primer”, Eastern Book Company.
Rowena Murray, “How to Write a Thesis”, Tata McGraw Hill Education Pvt. Ltd.
C.R.Kothari, "Research Methodology, New Age Publishers
Jeffrey A. Lee, “The scientific endeavor: a primer on scientific principles and practice”, Benjamin Cummings.
Robert A. Day, “How to Write and Publish a Scientific Paper”, Cambridge University Press.
Dr. Marlene Caroseli, “Quick Wits: 50 Activities for Developing Critical Thinking Skills”, Ane Books.
Gregory Bassham, William Irwin, Henry Nardone and james Wallace, “Critical Thinking: A Student’s Introduction”, Tata McGraw Hill education Pvt. Ltd.
Rhonda Abrams and Julie Vallone,” Winning Presentation in a Day”, PHI Pvt Ltd. 6. Weisberg, R., “Creativity - Beyond the Myth of Genius”, W.H. Freeman and Company, New York, 1993.