https://jmi.ac.in

Centre for Nanoscience and Nanotechnology
Jamia Millia Islamia, New Delhi-110025

M. Tech. (Nanotechnology) (Evening)

Duration of course: 2 Years (4 Semesters)
No of Credits: 80
Total Intake= 25+2
Mode= Self Financing
Eligibility for admission in M. Tech. Nanotechnology

(i) **B.Tech.** in all disciplines
(ii) **B.Sc. (Four-year)** degree in Physics, Chemistry and allied subjects
(iii) **M.Sc.** in Physics, Chemistry and allied subjects

SEMESTER I

CODE NO.	COURSE TITLE	L	P	T	CREDITS
MTNT1-01	Quantum Mechanics and Quantum Materials	4	0	0	4
MTNT1-02	Nanotechnology: Fundamentals and Properties	4	0	0	4
MTNT1-03	Advanced Characterization Techniques	4	0	0	4
MTNT1-04	Introduction to Nano-photonics	4	0	0	4
L1-01	Nanotechnology Lab I	0	3	0	3
MTNE-01	Elective 1: Nanofabrication and Cleanroom Processes	1	2	0	3
TOTAL CREDITS					**22**

SEMESTER II

CODE NO.	COURSE TITLE	L	P	T	CREDITS
MTNT1-01	MEMS/NEMS and Sensor Technology	4	0	0	4
MTNT1-02	Synthesis of Nanomaterials and Nanocomposites	4	0	0	4
MTNT1-03	Computational Nanoscience	4	0	0	4
MTNT1-04	Nanoelectronics	4	0	0	4
L2-02	Advance Nanotechnology Lab II	0	3	0	3
MTNE-02	Elective 2	3	0	0	3
TOTAL CREDITS					**22**

SEMESTER III

S. No.	Course	L	P	T	Credits
RM	Research Methodology	3	0	0	3
IKS	Indian Knowledge System (IKS)	3	0	0	3
P3-01	Minor Project	0	12	0	12
Total Credits					**18**

SEMESTER IV

Course	Course	Credits
M. Tech. Dissertation / Thesis	M. Tech. Dissertation / Thesis	18
Total Credits	**Total Credits**	**18**

SEMSETERS	CREDITS
SEMESTER I	22
SEMESTER II	22
SEMESTER III	18
SEMSTER IV	18
TOTAL CREDITS	**80**

Detailed Course Structure
M.Tech. (Nanotechnology) (Evening)

Centre for Nanoscience and Nanotechnology
Jamia Millia Islamia
New Delhi

SEMESTER I

MTNT1-01: Quantum Mechanics and Quantum Materials

Credits: 4, **Lectures:** 40, **Units:** 4

UNIT I: Fundamentals of Quantum Mechanics (10 Lectures)
Historical development of quantum theory, Failure of classical physics, Blackbody radiation, Photoelectric effect, Compton effect, Wave-particle duality, de Broglie matter waves, Wave packets, Phase and group velocity, Heisenberg uncertainty principle, Wave function and probability interpretation, Operators and observables, Eigenvalues and eigenfunctions, Expectation values, Commutators, Time-dependent and time-independent Schrödinger equations, Ehrenfest theorem.

UNIT II: Quantum Mechanics of Nanostructures (10 Lectures)
Particle in one-dimensional infinite and finite potential wells, Quantum tunnelling, Barrier penetration, Harmonic oscillator, Hydrogen atom, Quantum numbers, Orbital and spin angular momentum, Spin-orbit coupling, Pauli exclusion principle, Density of states in 3D, 2D, 1D and 0D systems, Quantum confinement, Quantum wells, Quantum wires, Quantum dots, Excitons, Optical transitions in low-dimensional nanostructures.

UNIT III: Electronic Structure and Quantum Theory of Solids (10 Lectures)
Reciprocal lattice, Brillouin zones, Bloch theorem and Bloch states, Nearly free electron model, Tight-binding approximation, Electronic band structure, Bandgap engineering, Fermi energy and Fermi surface, Effective mass, Intrinsic and extrinsic semiconductors, Direct and indirect bandgap semiconductors, Lattice vibrations, Phonons, Electron-phonon interaction, Optical properties of solids, Dielectric properties of solids, Magnetic properties of solids, Diamagnetism, Paramagnetism, Ferromagnetism, Antiferromagnetism, Ferrimagnetism.

UNIT IV: Quantum Materials and Emerging Quantum Technologies (10 Lectures)
Graphene, Transition metal dichalcogenides, van der Waals heterostructures, Topological quantum materials, Dirac and Weyl semimetals, Strongly correlated electron systems (overview), Superconductivity (BCS concept), Quantum Hall effect, Spintronics, Valleytronics, Quantum transport, Ballistic transport, Coulomb blockade, Single-electron devices, Point defects and defect states, Quantum coherence, Quantum phase transitions, Quantum materials for nanoelectronics, Optoelectronics, Quantum sensing, Quantum technologies.

Text Books

1. Griffiths, D. J., & Schroeter, D. F., **Introduction to Quantum Mechanics**, 3rd Edition, Cambridge University Press, 2018.
2. Kittel, C., **Introduction to Solid State Physics**, 8th Edition, John Wiley & Sons, 2005.
3. Simon, S. H., **The Oxford Solid State Basics**, Oxford University Press, 2013.
4. Ashcroft, N. W., & Mermin, N. D., **Solid State Physics**, Cengage Learning, 1976.

Reference Books

1. Sakurai, J. J., & Napolitano, J., **Modern Quantum Mechanics**, 3rd Edition, Cambridge University Press, 2020.

MTNT1-02: Nanotechnology: Fundamentals and Properties

Credits: 4, **Lectures:** 40, **Units:** 4

Unit-I: Background to Nanoscience

Importance of Nanotechnology, History of Nanotechnology-Opportunity at the nano scale-length: Definition of Nano, Scientific revolution-emergence and challenges of nanoscience and nanotechnology, carbon age-new form of carbon (CNT to Graphene). Zero- dimensional nanostructures: Nanoparticles. One-dimensional Nanostructures: Nanotubes, Nanorods and Nanowires. Two-dimensional Nanostructures: Nanofilms, Nanolayers and Nanocoatings. Three-dimensional Nanomaterials. Nanoporous materials. Size effect of Nanomaterials: Size -Melting point and phase transition processes- quantum-size-effect (QSE), shape, density, wetability and specific surface area.

Unit-II: Industrial Nanotechnology

Nanotechnology in Textiles and Cosmetics Textiles: Nanofibre production Swim-suits with shark-skin effect, Soil repellence, Lotus effect - Nano finishing in textiles; Cosmetics: Formulation of Gels, Shampoos (Micellar self-assembly and its manipulation) – Sun-screen dispersions for UV protection, colour cosmetics. Nanotechnology in Defence: Camouflage distributed sensors - Mini-/Micro robots - Bio-technical hybrids - Small satellites and Space launchers - Nanotechnology in Agriculture, Nanotechnology in Food industry – Nanopackaging for enhanced shelf life - Smart/Intelligent packaging - Food processing and food safety.

Unit-III: Nanotechnology - Environmental and health effects

Environmental pollutants in air, water, soil, hazardous and toxic wastes, application of nanotechnology in remediation of pollution. - The challenge to occupational health and hygiene, toxicity of nanoparticles, effects of inhaled nanosized particles, skin exposure to nanoparticles, impact of CNTs on respiratory systems, hazards and risks of exposure to nanoparticles, monitoring nanoparticles in workplace and sensors.

UNIT IV: Physical Properties of Nanomaterials

Classification of Nanomaterials: 0D, 1D and 2D nanostructures, Quantum confinement and size-dependent thermal, electronic and optical properties, Electronic properties: Band structure, Density of States (bulk, quantum wells, quantum wires and quantum dots), Charge transport in nanostructures: Ballistic transport, Quantized conductance, Coulomb blockade Optical properties: Optical absorption, Photoluminescence, Excitons Magnetic properties: Superparamagnetism, Nanomagnetism, Giant Magnetoresistance (GMR), Hall Effect: Hall coefficient, Hall mobility and their applications in nanomaterial characterization

Reference Books:

1. Nanoparticles: From theory to applications – G. Schmidt, Wiley Weinheim , 2004
2. J. Altmann, Routledge, Military Nanotechnology: Potential Applications and Preventive Arms Control, Taylor and Francis Group, 2006.
3. Jennifer Kuzma and Peter VerHage, Nanotechnology in agriculture and food production, Woodrow Wilson International Center, (2006).

4. Lynn J. Frewer, Willehm Norde, R. H. Fischer and W. H. Kampers, Nanotechnology in the Agri-food sector, Wiley-VCH Verlag, (2011).
5. P. J. Brown and K. Stevens, Nanofibers and Nanotechnology in Textiles, Woodhead Publishing Limited, Cambridge, (2007)

MTNT1-03: Advanced Characterization Techniques

Credits: 4, **Lectures:** 40, **Units:** 4

Unit I: Structural Characterization

Understanding the crystalline arrangement and phase composition of materials, X-Ray Diffraction (XRD): Principles of Bragg's Law, phase identification, crystallite size determination (Scherrer equation), and lattice parameter calculations, Selected Area Electron Diffraction (SAED): Interpretation of diffraction spots vs. rings, indexing patterns to determine crystal systems and zone axes, Raman Spectroscopy: Inelastic scattering to identify vibrational modes, Structural fingerprinting for carbon allotropes (G and D bands) and phase transitions, X-ray Photoelectron Spectroscopy (XPS): Analyzing elemental composition and chemical bonding states (oxidation states) at the surface.

Unit II: Optical Characterization

Probing interactions of materials with light to determine electronic band structures, UV-Visible Spectroscopy (UV-Vis): Absorption and reflectance measurements, Tauc plot bandgap analysis, Photoluminescence (PL): Radiative recombination processes, defects, impurities and exciton behavior in semiconductors, Ellipsometry: Measuring thin-film thickness and refractive index by analyzing changes in light polarization.

Unit III: Morphological & Topographical Characterization

Visualizing the physical shape, size, and surface roughness at the micro and nano scales, FE-SEM: High-resolution surface imaging using a cold-cathode field emission source, Energy Dispersive X-ray Analysis (EDX) for elemental mapping, Transmission Electron Microscopy (TEM): Internal structure imaging at sub-nanometer resolution. High-Resolution TEM (HRTEM) for visualizing individual atomic planes, Atomic Force Microscopy (AFM): Contact, non-contact, and tapping modes, 3D surface mapping, roughness measurement, and nanomechanical properties.

Unit IV: Thermal & Magnetic Characterization

Thermogravimetric Analysis (TGA): Measuring mass change vs temperature to study thermal stability, Vibrating Sample Magnetometry (VSM): Analyzing hysteresis loops to determine coercivity and saturation magnetization.

Reference Books:

1. Cullity, B. D. and Stock, S. R., Elements of X-Ray Diffraction, 3rd Edition, Pearson, 2001.
2. Goldstein, J. I., Newbury, D. E., Michael, J. R., Ritchie, N. W. M., Scott, J. H. J. and Joy, D. C., Scanning Electron Microscopy and X-Ray Microanalysis, 4th Edition, Springer, 2018.
3. Williams, D. B. and Carter, C. B., Transmission Electron Microscopy: A Textbook for Materials Science, 2nd Edition, Springer, 2009.

4. Skoog, D. A., Holler, F. J. and Crouch, S. R., Principles of Instrumental Analysis, 7th Edition, Cengage Learning, 2017.
5. Stuart, B. H., Infrared Spectroscopy: Fundamentals and Applications, Wiley

MTNT1-04: Introduction to Nano-photonics

Credits: 4, **Lectures:** 40, **Units:** 4

Unit-I: Concepts for Nanophotonics
Comparison between photons and electrons: free space propagation and confinement. Concept of Photonic Bandgap. Analogy between Photonic and Electronic Bandgap. Propagation of electromagnetic waves in bulk, across interface and across nanofilm. Concept of Optical modes, Group velocity, Dispersion characteristics and group velocity dispersion associated with propagating electromagnetic fields. Photons inside periodic structures. Bloch modes: Dynamics of Bloch modes, Coupled mode theory.

Unit-II: Optical nanostructures and quantum confinement
One-dimensional confinement: quantum wells, two-dimensional confinement: quantum wires, and three-dimensional confinement: quantum dots. Optical properties in confined structures. Interaction of electromagnetic waves with nanoparticles (0-D); nanotubes, nanorods and nanowires (1-D); Nanofilm, nanolayers and nanocoatings (2-D). Optical response of nanoporous materials: Bruggeman's effective index method.

Unit-III: Photonic Crystals
One-, two-, and three-dimensional photonic crystals. Properties of photonic bandgap. Defects in photonic crystals and concept of microcavity. Fabrication technique and challenges for photonic crystals. Photonic wave guides, Photonic Crystal Fibers, Quantum-well laser, QWID. Biophotonic applications. Photonic crystal based mirrors and omni-directional reflectors. Optical sensing application.

Unit-IV: New approaches in nanophotonics
Near Field Optics-Apertureless near field optics-near field scanning optical microscopy (NSOM or SNOM)-SNOM based detection of plasmonic energy transport-SNOM based visualization of waveguide structures-SNOM in nanolithography-SNOM based optical data storage and recovery-generation of optical forces-optical trapping and manipulation of single molecules and cells in optical confinement-laser trapping and dissection for biological systems.

Reference Books:

1. Nanophotonics : Paras N. Prasad
2. Nanophotnics : H. Rigneault, J-M Lourtioz, C. Delalande and Ariel Levenson
3. Photonic Crystals: Moulding the Flow of Light: J. D. Joannopoulos et al.
4. M. Ohtsu, K. Kobayashi, T. Kawazoe and T. Yatsui, ―Principals of Nanophotonics (Optics and Optoelectronics)" University of Tokyo, Japan, (2003).

L1-01: Nanotechnology Lab I

Experiment 1
Synthesis of ZnO Nanoparticles by the Sol–Gel Method
Objective: To synthesize zinc oxide nanoparticles using the sol–gel technique and understand the effect of reaction parameters on nanoparticle formation.

Experiment 2
Synthesis of TiO_2 Nanoparticles by the Sol–Gel Method
Objective: To prepare titanium dioxide nanoparticles through controlled hydrolysis and condensation of a titanium precursor.

Experiment 3
Synthesis of Silver Nanoparticles by Chemical Reduction
Objective: To synthesize silver nanoparticles by reducing silver nitrate using sodium borohydride or sodium citrate and study colloidal nanoparticle formation.

Experiment 4
Synthesis of Fe_3O_4 Magnetic Nanoparticles by the Co-precipitation Method
Objective: To prepare magnetite nanoparticles by chemical co-precipitation of ferrous and ferric salts under alkaline conditions.

Experiment 5
Synthesis of CuS Nanoparticles by the Chemical Precipitation Method
Objective: To synthesize copper sulfide nanoparticles by reacting copper salt with sodium sulfide and investigate precipitation-based nanoparticle formation.

Experiment 6
Synthesis of Silica (SiO_2) Nanoparticles by the Stöber Method
Objective: To synthesize monodispersed silica nanoparticles through controlled hydrolysis and condensation of tetraethyl orthosilicate (TEOS).

Experiment 7
Hydrothermal Synthesis of Carbon Dots
Objective: To synthesize fluorescent carbon dots by the hydrothermal carbonization of citric acid and investigate their optical properties.

Experiment 8
Preparation of Nanostructured ZnO Thin Films by Spin Coating
Objective: To fabricate nanostructured ZnO thin films using the spin-coating technique followed by thermal annealing.

Experiment 9
Self-Assembly of Nanoparticles by Solvent Engineering
Objective: To fabricate ordered nanoparticle assemblies through controlled solvent evaporation and antisolvent-assisted self-assembly.

Experiment 10
Synthesis of Nanostructured Powder by High-Energy Ball Milling
Objective: To synthesize nanostructured powder from bulk materials using a high-energy planetary ball mill and study the effect of milling parameters on particle size reduction.

Credit Course (Elective)
MTNE-01: Nanofabrication and Cleanroom Processes

Credits: 3: L-01, P-02

Module 1: Cleanroom Infrastructure, Vacuum Systems, and Patterning

• Cleanroom Protocols & Safety Engineering

Theory: Classification of cleanrooms (ISO 1 to ISO 9, Federal Standard 209E), laminar airflow, HVAC systems, particle dynamics, and contamination control.

Operational Rules: Gowning protocols, personal protective equipment (PPE), chemical handling safety (MSDS), and emergency shutdown procedures.

• Vacuum Science & Thin Film Deposition

Theory: Fundamentals of vacuum (rough, high, and ultra-high vacuum), gas laws, pumps (rotary, diffusion, turbomolecular, and cryo-pumps), and vacuum gauges.

Deposition Mechanisms: Physical Vapor Deposition (PVD: Sputtering, E-beam Evaporation) and Chemical Vapor Deposition (CVD/ALD).

• Lithography & Pattern Transfer

Theory: Photolithography fundamentals (photoresists, exposure tools, masks, alignment) alongside wet chemical etching mechanics, selectivity, and isotropy.

Wet Bench Operations: Acid/base benches, solvent cleaning (RCA cleaning protocols), safety procedures for Hydrofluoric (HF) acid, and chemical waste disposal.

Module 2: Advanced Etching and MEMS/NEMS Virtual Fabrication

• Advanced Dry & Plasma Etching Systems

Theory: Plasma physics fundamentals, Reactive Ion Etching (RIE), Deep Reactive Ion Etching (DRIE), and Inductively Coupled Plasma (ICP) etching.

Mechanisms: Physical sputtering vs. chemical reaction, anisotropy control, aspect-ratio dependent etching (ARDE), and micro-trenching phenomena.

• MEMS/NEMS Architectures & Virtual IC Fabrication (VIT)

Theory: Introduction to MEMS/NEMS device architectures (cantilevers, sensors) and an overview of the Virtual IC Technology (VIT) framework.

Design & System Setup: Principles of installing, configuring, and deploying VIT software environments across a networked computer lab for multi-user simulation.

Module 3: Virtual Practical Lab Framework using SEMulator3D

S.No.	Assignment
1.	Install SEMulator3D and run an example

2. Create a layout of NMOS, PMOS and inverter in SEMulator3D
3. LOCOS isolation verses Shallow Trench Isolation (STI)
4. Gate-first verses Gate-last
5. Spacer and multiple patterning
6. Replacement metal gate
7. Implantation & Silicidation
8. Damascene Process
9. Dual Damascene Process

Reference Books:

1. Jaeger, R. C., **Introduction to Microelectronic Fabrication**, 2nd Edition, Pearson, 2001.
2. Madou, M. J., **Fundamentals of Microfabrication and Nanotechnology**, 3rd Edition, CRC Press, 2011.
3. Franssila, S., **Introduction to Microfabrication**, 2nd Edition, Wiley, 2010.
4. Williams, K. R., Gupta, K. and Wasilik, M., **Etch Rates for Micromachining Processing**, Journal of Microelectromechanical Systems, 2003. *(Useful technical reference for wet/dry etching processes.)*

SEMESTER II

MTNT2-01: MEMS/NEMS and Sensors Technology

Credits: 4, **Lectures:** 40, **Units:** 4

Unit I: Fundamentals of Microfabrication

Cleanroom fundamentals, contamination control, wafer cleaning and surface preparation, Oxidation, Thin film deposition techniques, Physical vapor deposition, Chemical vapor deposition, atomic layer deposition, Epitaxy. Fundamentals of photolithography, photoresists, resolution and process limitations.

Unit II: Etching and Pattern Transfer Techniques

Wet chemical etching, plasma etching, reactive ion etching, deep reactive ion etching (DRIE), Ion beam etching and milling, Lift-off process, Pattern transfer, Surface and bulk micromachining, lithography fundamentals, Electron beam lithography (EBL), Focused ion beam (FIB), Nanoimprint lithography (NIL).

Unit III: Doping, Metallization and Process Integration

Diffusion and ion implantation, Annealing processes and defect engineering, Metallization, Ohmic and Schottky contacts, Interconnects and barrier layers, Dielectrics and passivation layers, Process integration for CMOS and advanced devices, Yield, Process control and reliability issues.

Unit IV: Advanced Fabrication Technologies

MEMS and NEMS fabrication, 2D materials fabrication and transfer techniques, Flexible and wearable device fabrication, 3D micro/nano printing, quantum device fabrication, Heterogeneous integration and packaging, Lab-on-chip and microfluidic fabrication, AI-assisted fabrication,

Reference Books:

- S. M. Sze and Kwok K. Ng, *Physics of Semiconductor Devices*, (Wiley)
- Marc Madou, *Fundamentals of Microfabrication and Nanotechnology*, (CRC Press)

MTNT2-02: Synthesis of Nanomaterials and Nanocomposites

Credits: 4, **Lectures:** 40, **Units:** 4

Unit-I: Physical Methods of Synthesis of Nanomaterials

Introduction: Synthesis and nanofabrication, Bottom-Up versus Top-Down. Synthesis of Nano-structured materials: Principle and relative merits of each technique for production of nanostructures including ultra-thin films and multilayer by: (a) Laser Ablation technique, (b) Arc Discharge technique and (c) Mechanical Milling.

Unit-II: Physico-Chemical Methods of Synthesis of Nanomaterials

Fundamentals and need of identification of pertinent parameters amenable to synthesis of nanoparticles by Physio-chemical methods such as (a) CVD (Chemical Vapor Deposition), (b) Plasma / Sputtering method, (c) Atomic Layer Epitaxy.

Unit-III: Chemical Methods of Synthesis of Nanomaterials

Solid-, liquid-, and gas-phase synthesis of nanomaterials; nucleation and growth mechanisms; control of particle size, shape and morphology; precipitation, co-precipitation, hydrothermal, solvothermal, microemulsion and chemical reduction methods; sol-gel method; vapour–liquid–solid (VLS) and solution–liquid–solid (SLS) growth; role of surfactants, capping agents and stabilizers; solution-based growth techniques for 1D and 2D nanostructures; synthesis of metallic, oxide and semiconducting nanoparticles.

UNIT IV: Nanocomposites and its classifications

Introduction, Concept of composite materials, Matrix materials, Functions of a Matrix, Desired Properties of a Matrix, Classification based on Matrix Material: Organic Matrix composites, Polymer matrix composites (PMC), Carbon matrix Composites or Carbon-Carbon Composites, Metal matrix composites (MMC), Ceramic matrix composites (CMC); Classification based on reinforcements: Fiber Reinforced Composites, Fiber Reinforced Polymer (FRP) Composites, Laminar Composites, Particulate Composites, Types of Reinforcements/Fibers: Role and Selection or reinforcement materials, Types of fibres, Glass
fibers, Carbon fibers, Aramid fibers, Metal fibers, Advantages, limitations and applications of Nanocomposites.

Reference Books:

1. Chemistry of nanomaterials: Synthesis, properties and applications by CNR Rao et.al.
2. Nanoparticles: From theory to applications – G. Schmidt, Wiley Weinheim 2004.
3. Processing & properties of structural Nanomaterials - Leon L. Shaw (editor).
4. Handbook of Nanotechnology, Bharat Bhushan, Springer.
5. Nanostructures and Nanomaterials: Guozhong Cao & Ying Wang (World Scientific

MTNT2-03: Computational Nanoscience

Credits: 4, **Lectures:** 40, **Units:** 4

UNIT I – Computational Methods and Modelling
Computational Modelling of Nanomaterials, Mathematical and Numerical Methods, Potential Energy Surfaces, Interatomic Potentials, Boundary Conditions and Simulation Cells, Periodic Systems, Computational Algorithms, Numerical Optimization, Computational Accuracy and Convergence

UNIT II – Statistical and Atomistic Simulation
Statistical Mechanics and Computational Methods, Monte Carlo Simulation, Ising Model, Metropolis Algorithm, Molecular Dynamics Simulation, Molecular Mechanics, Force Fields and Interatomic Potentials, Thermodynamic and Structural Properties, Phase Transitions and Critical Phenomena

UNIT III – Quantum Computational Methods
Quantum Mechanical Modelling, Electronic Structure Methods, Hartree–Fock Method, Density Functional Theory, Exchange-Correlation Functionals, Plane-Wave and Localized-Basis Methods, Electronic Structure Calculations, Computational Study of Structural, Electronic and Magnetic Properties

UNIT IV – Computational Modelling and Advanced Applications
Computational Modelling of Nanoparticles, Nanotubes and Nanowires, Graphene and Two-Dimensional Materials, Surfaces, Interfaces and Defects, Computational Nanocatalysis, Mechanical and Thermal Properties, Electronic and Optical Properties, Multiscale Modelling, Machine Learning and Data-Driven Nanoscience

Reference Books:

1. D. Frenkel and B. Smit, **Understanding Molecular Simulation: From Algorithms to Applications**, Academic Press.
2. M. P. Allen and D. J. Tildesley, **Computer Simulation of Liquids**, Oxford University Press.
3. K. Binder and D. W. Heermann, **Monte Carlo Simulation in Statistical Physics**, Springer.
4. R. M. Martin, **Electronic Structure: Basic Theory and Practical Methods**, Cambridge University Press.
5. D. C. Rapaport, **The Art of Molecular Dynamics Simulation**, Cambridge University Press

MTNT2-04: Nanoelectronics

Credits: 4, **Lectures:** 40, **Units:** 4

Unit I: Fundamentals of Nanoelectronics
Introduction to nanoelectronics, Moore's law and scaling challenges, Limits of CMOS technology, Quantum effects in nanoscale devices, Quantum confinement, Electron transport mechanisms, Ballistic transport, Coulomb blockade, Tunnelling phenomena.

Unit II: Nanomaterials for Nanoelectronics
Carbon nanotubes (CNTs), Graphene and graphene derivatives, Semiconductor nanowires and nanorods, Quantum dots, 2D materials, Wide bandgap semiconductors (GaN, SiC, β-Ga_2O_3), Nanocomposites and hybrid nanomaterials, Electronic and optoelectronic properties of nanomaterials.

Unit III: Nano-electronic Devices
Nanoscale MOSFETs, FinFETs, Nanowire FETs, Graphene field-effect transistors, Single Electron Transistors (SETs), Resonant Tunnelling Diodes, Quantum well and quantum dot devices, Nano-electronic sensors and photodetectors.

Unit IV: Emerging Nano-electronic Technologies
Resistive switching devices (Memristors and RRAM), Phase Change Memory (PCM), Magnetic RAM (MRAM), Spintronics and spin-based devices, Neuromorphic computing hardware, Quantum computing devices, Flexible and wearable nanoelectronics, Artificial Intelligence (AI) hardware accelerators, Future trends in nanoelectronics

Reference Books:

- S. M. Sze and Kwok K. Ng, *Physics of Semiconductor Devices*, (Wiley)
- Supriyo Datta, *Quantum Transport: Atom to Transistor*, (Cambridge University Press).

SEMESTER III

Research Methodology

Credits: 3, **Lectures:** 30, **Units:** 3

UNIT I: Introduction to Research

The concept of research, characteristics of good research, Application of Research, Meaning and sources of Research problem, characteristics of good Research problem, Research process, outcomes, application of Research, Meaning and types of Research hypothesis, Importance of Review of Literature, Organizing the Review of Literature.

UNIT II: Types of Research

Types of research: pure (basic, fundamental) and applied research, qualitative and quantitative. Research Design : Meaning, need, types of research design – Exploratory, Descriptive, Casual research Design, Components of research design, and Features of good Research design, Experiments, surveys and case study Research design.

UNIT III: Sampling, Data Collection and Research Report:

Types and sources of data – Primary and secondary, Methods of collecting data, Concept of sampling and sampling methods – sampling frame, sample, characteristics of good sample, Research Report : Research report and its structure, journal articles – Components of journal article, Thesis and dissertations, components of thesis and dissertations. Referencing styles and bibliography.

Reference Books:

1. Donald Cooper and PS Schindler (2009) Business Research Methods, 9th edition, Tata McGraw Hill.
2. Kothari, C. R. Research Methodology: Methods and Techniques. 2nd ed., New Age International Publishers, 2004.
3. Kerlinger, F.N. (1986) Foundations of Behavioral Research. 3rd Edition, Holt, Rinehart and Winston, New York.

Indian Knowledge System (IKS)

Credits: 3, **Lectures:** 30, **Units:** 3

Unit I: Introduction to IKS

Caturdaśa Vidyāsthānam, 64 Kalas, Shilpa Śāstra, Four Vedas, Vedāṅga,, Indian Philosophical Systems, Vedic Schools of Philosophy (Sāṃkhya and Yoga, Nyaya and Vaiśeṣika, Pūrva Mīmāṃsā and Vedānta), Non-Vedic schools of Philosophical Systems (Cārvāka, Buddhist, Jain), Puranas (Maha-puranas, Upa-Puranas and Sthala-Puranas), Niti Sastras, Subhasitas.

Unit II: Indian Traditional Knowledge; Science and Practices

Introduction to the Science and way of doing science and research in India, Ancient Science in Intra & Inter Culture Dialogue & coevolution. Traditional agricultural practices, Traditional water-harvesting practices, Traditional Livestock and veterinary Sciences Traditional Houses & villages, Traditional Forecasting, Traditional Ayurveda & plant based medicine, Traditional writing Technology

Unit III: Physics in India

Vaisheshika darshan, atomic theory & law of motion, theory of panchmahabhoota, Brihath Shathaka (divisions of the time, unit of distance), bhaskarachaya (theory of gravity, surya siddhanta & sidhanta shriomani), Lilavati (gurutvakashan Shakti).
Indian S & T Heritage ,sixty-four art forms and occupational skills (64 Kalas) Metals and Metalworking technology (Copper, Gold, Zinc, Mercury, Lead and Silver), Iron & Steel, Dyes and Painting Technology).

Reference Books:

1. Introduction to Indian Knowledge System: Concepts and Applications, Authors: B. Mahadevan, Vinayak Rajat Bhat, Nagendra Pavana R.N., Publisher: PHI Learning Pvt. Ltd.
2. India's Rebellious Technology & Heritage in Metallurgy / Ancient Mining and Metallurgy in India Authors: D. P. Agrawal / A. K. Biswas, Publisher: Munshiram Manoharlal Publishers.

P-01: Minor Project

M.Tech students must take a substantial research type project during the study period. Projects are generally based in one of the nanoscience/technology research groups and involve a structured experimental investigation of a research or development nature.

SEMESTER IV

P-02: Project Presentation Examination (Major Project)

M.Tech students must take a substantial research type project during the study period. Projects are generally based in one of the Materials Science/technology research groups and involve a structured experimental investigation of a research or development nature.