M.Tech (Nanotechnology)

Syllabus

Centre for Nanoscience and Nanotechnology

Jamia Millia Islamia (Central University)

New Delhi-110025

The M.Tech Nanotechnology course started in Department of Physics in July 2007, and since 2015 the course is being run in an independent 'Centre for Nanoscience and Nanotechnology'. The objective of the course is to give students a through grounding in the skills necessary for a technically based carrier in the new high-tech industries in which the manufacturing of multifunctional devices with dimension in the micron or nanometer range is involved.

This course gives an introduction into basic fabrication and characterization techniques currently used or being developed for the development of nanometer scale devices and materials. The course would equip graduates with the skills to make a successful career in the new industries where reduced dimensionality pays a critical role in their products. It is designed as a series of lecture modules covering the technologies used to design, realize and analyze the micro and nano-scale devices, materials and systems, coupled with the general and technology management. These are supported by project works, undertaken on both a group and an individual basis and conducted in close collaboration with Industries/Laboratories.

The Centre for Nanoscience and Nanotechnology has a good infrastructure with well equipped laboratories. It consists of equipments like Thermal Evaporation Unit to produce nanoparticles, RF Sputtering, Spin Coating Unit to prepare the nanostructure by chemical route, Low Pressure Chemical Vapor Deposition (LPCVD) for the growth of carbon nanotubes, ECR Plasma etching system and Scanning Electron Microscope to study the morphology of the nanostructures. To study the spectroscopic analysis UV Visible Spectrophotometer, FTIR and Fluorescence Spectrophotometer are also available.

The M.Tech Nanotechnology course consist of four semesters which includes first two semesters (first and second semesters, 6 months each) fully dedicated to the theory courses and last two semester (third and fourth semesters, 6 months each) comprises research project dissertations to be undertaken in an establishment research lab/industry.

JAMIA MILLIA ISLAMIA

Centre for Nanoscience and Nanotechnology, JMI

Course Structure M.Tech (Nanotechnology)

Semester I

Paper code	Subject title	Teacher`s Name
MTN 1-01	Solid State Electronics	Prof. S. S. Islam
MTN 1-02	Fundamentals of Nanoscience and Nanotechnology	Dr. Manika Khanuja
MTN 1-03	Properties of Nanomaterials	Dr. Shahab Ahmad
MTN 1-04	Foundation in Micro &Nano-systems	Dr. Prabhash Mishra
MTN 1-05	Synthesis of Nanomaterials	Dr. Samina Hussain
MTN 1-06	Quantum Theory and Modelling of Nanostructures	Dr. A.K. Hafiz

Semester II

Paper code	Subject title	Teacher`s Name
MTN 2-01	MEMS/NEMS and Sensors Technology	Dr. Prabhash Mishra
MTN 2-02	Characterization of Nanomaterials	Prof. S. S. Islam
MTN 2-03	Surface Engineering for Nanotechnology	Dr. Manika Khanuja
MTN 2-04	Introduction to Nanophotonics	Dr. A.K. Hafiz
MTN 2-05	Nanomaterials For Energy Applications	Dr. Shahab Ahmad
MTN 2-06	Nanocomposite Materials	Dr. Samina Hussain

Semester III

Paper code	Subject title	Teacher`s Name
P-01	Project Presentation Examination	

Note: There are **two mid-term presentation** to analyze the project progress.

Semester IV

Paper code	Subject title	Teacher`s Name
P-02	Project Presentation Examination	

Note: There are **two mid-term presentation** to analyze the project progress.

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

M.Tech (Nanotechnology)

Course of Study and Scheme of Examination

FIRST SEMESTER

Course No.	Subjects	CREDITS	Periods per week			Distribution of Marks			
			L	T	P	Mid Semester Evaluation		End Semester Exams	Total
						CWS	MST		
MTN 1-01	Solid State Electronics	4	3	1	-	10	30	60	100
MTN 1-02	Fundamentals of Nanoscience and Nanotechnology	4	3	1	-	10	30	60	100
MTN 1-03	Properties of Nanomaterials	4	3	1	-	10	30	60	100
MTN 1-04	Foundation in Micro &Nano-systems	4	3	1	-	10	30	60	100
MTN 1-05	Synthesis of Nanomaterials	4	3	1	-	10	30	60	100
MTN 1-06	Quantum Theory and Modelling of Nanostructures	4	3	1	-	10	30	60	100
	Total Credits	**24**	**18**	**6**		**60**	**180**	**360**	**600**

CWS – Class Work Sessionals

MST – Monthly Sessional Tests

M. Tech. Nanotechnology

Semester-I

MTN1-01 : Solid State Electronics

Unit-I: Semiconductors Crystalline and Amorphous

Bonds and Bands: Form of the forces, atomic bonding, energy band formation, classification of solids, crystal structure, diamond and zinc-blende structure, Crystal defects, Lattice disorder. Practical Semiconductors: Intrinsic and Extrinsic semiconductors, Effective mass, density of states, Fermi-Dirac statistics, Law of Mass Action, Fermi level Fermi level and its dependence on temperature and doping, Effect of heavy doping, doping of excess carriers, Ampohoteric doping, Auto doping and modulation doping , Mobility studies under electric field, doping conc. And temperature,

Unit-II: **Bandstructure engineering: Alloys & Hetrostructures**

Bandgap engineering techniques, alloying phenomenon, Heterostructures: Devices based on quantum confinement of carriers, Bandstructure of semiconductors alloys-GaAs-AlAs alloy, InAs-GaAs alloy, HgTe-CdTe alloy & Si-Ge alloy; Bandstructure modification by Hetrostructures, Electron-affinity rule, Transitivity of band discontinuities, Bandstructure in quantum wells and superlattice, Bandstructure Modification due to lattice mismatch in epitaxy.

Unit III: Electrical properties of semiconductors

Electrical conduction in solids, Intrinsic and Impurity conduction in semiconductors, Scattering of semiconductors, velocity – electric field relations, Carrier transport under high field, breakdown phenomenon, carrier transport by diffusion, carrier transport under drift and diffusive force, Hall Effect studies.

Unit IV: Optical properties of semiconductors

Carrier generation and recombination processes, Optical absorptions, Luminescence: photoluminescence, cathodoluminescence, Electroluminescence, Carrier lifetime and its measurement techniques, photoconductivity, Diffusion of carriers and its related phenomena in optical devices.

Reference Books:

1. J. S. Blakemore, Solid State Physics, Academic Press.
2. J. S. Blakemore, Statics of Semiconductors, Dover Publications.
3. Jaspreet Singh, An Introduction of Semiconductors Physics, Mc-Graw Hill (Int.)
4. Kittel, Solid State Physics, Wiley Publications.
5. M. Rosenberg, Solid State Physics, Cambridge Univ. Press.

MTN1-01 : Solid State Electronics

TEACHING PLAN

S.No.	Title	Period	Teacher`s Name
1	Form of the forces, atomic bonding, Energy band formation, and classification of solids	02	**Prof. S.S. Islam**
2	crystal structure, diamond and zinc-blende structure, Crystal defects, Lattice disorder	02	-do-
3	Intrinsic and Extrinsic semiconductors, Effective mass, density of states, Mobility studies under electric field, doping conc. and temperature	02	-do-
4	Fermi-Dirac statistics, Law of Mass Action, Fermi level and its dependence on temperature and doping	02	-do-
5	Effect of heavy doping, doping of excess carriers, Ampohoteric doping, Auto doping and modulation doping	02	-do-
6	Bandgap engineering techniques, alloying phenomenon	02	-do-
7	Heterostructures: Devices based on quantum confinement of carriers	02	-do-
8	Bandstructure of semiconductors alloys- GaAs-AlAs alloy, InAs-GaAs alloy, HgTe-CdTe alloy & Si-Ge alloy	02	-do-
9	Band structure modification by Hetrostructures, Electron-affinity rule, Transitivity of band discontinuities	02	-do-
10	Bandstructure in quantum wells and superlattice, Bandstructure Modification due to lattice mismatch in epitaxy	02	-do-
11	Electrical conduction in solids	02	-do-
12	Intrinsic and Impurity conduction in semiconductors	02	-do-
13	Scattering of semiconductors, velocity – electric field relations	02	-do-
14	Carrier transport under high electrical field, breakdown phenomenon	02	-do-
15	carrier transport by diffusion; carrier transport under drift and diffusive force, Hall Effect studies	02	-do-
16	Carrier generation and recombination processes, Optical absorptions	02	-do-
17	Luminescence: photoluminescence, cathodoluminescence, Electroluminescence	02	-do-
18	Carrier lifetime and its measurement techniques	02	-do-
19	Photoconductivity, Diffusion of carriers and its related phenomena in optical devices.	04	-do-
		Total 40 h	

M. Tech. Nanotechnology

Semester-I

MTN1-02 : Fundamentals of Nanoscience and Nanotechnology

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)

Unit-II: Types of Nanomaterials

Zero- dimensional nanostructures: Nanoparticles. One-dimensional Nanostructures: Nanotubes, Nanorods and Nanowires. Two-dimensional Nanostructures: Nanofilms, Nanolayers and Nanocoatings. Three-dimensional Nanomaterials. Nanoporous materials. Polymer Nanocomposites. Size effect of Nanomaterials: Size -Melting point and phase transition processes- quantum-size-effect (QSE). Size induced metal-insulator-transition (SIMIT) , shape, density, wet ability and specific surface area.

Unit-III: 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-IV: 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 CNT s on respiratory systems, hazards and risks of exposure to nanoparticles, monitoring nanoparticles in work place and sensors.

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)

MTN1-02 : Fundamentals of Nanoscience and Nanotechnology

TEACHING PLAN

S.No.	Title	Period	Teacher`s Name
1	**Background to Nanoscience:** Importance of Nanotechnology.	02	**Dr. Manika Khanuja**
2	Opportunity at the nano scale-length: Definition of Nano.	02	-do-
3	Scientific revolution-emergence and challenges of nanoscience and nanotechnology.	02	-do-
4	Carbon age-new form of carbon (CNT to Graphene).	02	-do-
5	**Types of Nanomaterials:** Zero- dimensional nanostructures: Nanoparticles.	02	-do-
6	One-dimensional Nanostructures: Nanotubes, Nanorods and Nanowires.	02	-do-
7	Two-dimensional Nanostructures: Nanofilms, Nanolayers and Nanocoatings.	02	-do-
8	Three-dimensional Nanomaterials. Nanoporous materials. Polymer Nanocomposites.	02	-do-
9	Size effect of Nanomaterials: Size -Melting point and phase transition processes- quantum-size-effect (QSE).	02	-do-
10	Size induced metal-insulator-transition (SIMIT) , shape, density, wet ability and specific surface area.	02	-do-
11	**Industrial Nanotechnology:** Nanotechnology in Textiles and Cosmetics Textiles: Nanofibre production Swim-suits with shark-skin effect.	02	-do-
12	Soil repellence, Lotus effect - Nano finishing in textiles; Cosmetics: Formulation of Gels, Shampoos (Micellar self-assembly and its manipulation).	02	-do-
13	Sun-screen dispersions for UV protection, colour cosmetics..	02	-do-
14	Nanotechnology in Defence: Camouflage distributed sensors - Mini-/Micro robots.	02	-do-
15	Bio-technical hybrids - Small satellites and Space	02	-do-

	launchers - Nanotechnology in Agriculture.		
16	Nanotechnology in Food industry – Nanopackaging for enhanced shelf life - Smart/Intelligent packaging - Food processing and food safety.	02	-do-
17	**Nanotechnology - Environmental and health effects:** Environmental pollutants in air, water, soil, hazardous and toxic wastes, application of nanotechnology in remediation of pollution.	02	-do-
18	The challenge to occupational health and hygiene, toxicity of nanoparticles.	02	-do-
19	Effects of inhaled nanosized particles, skin exposure to nanoparticles, impact of CNTs on respiratory systems.	02	-do-
20	Hazards and risks of exposure to nanoparticles, monitoring nanoparticles in work place and sensors.	02	-do-
		Total = 40 h	

M. Tech. Nanotechnology

Semester-I

MTN1-03 : Properties of Nanomaterials

Unit-I: Thermal and Electronic Properties
Classifications of Nanomaterials: 2D, 1D and 0D systems, Role of Size on Thermal and Electronic properties of nanomaterials. Classification of Materials: Metal, Semiconductor, Insulator, Band structures, Mobility, Resistivity, Relaxation time, Hall effect: Hall voltage, Hall mobility, Hall Coefficient, Generation and Recombination: Radiative and Non-Radiative recombination, Net recombination rate equation, excess minority lifetime.

Unit-II: Optical Properties
Optical Absorption and Transmission, Photoluminescence, Fluorescence and Phosphorescence, Excitons: Properties and Types of Excitons, Basic concepts of Photoconductivity: photoconductive gain, Recombination time, transit time, time dependent and steady state carrier density, Electroluminescence in Fluorescent and Phosphorescent materials.

Unit-III: Confinement and Transport in nanostructure
Density of States for bulk system, Density of States of Quantum Wells, Wires and Dots, Conductance formula for nanostructures, Quantized conductance, Ballistic transport, Coulomb blockade.

Unit-IV: Magnetic Properties
Fundamentals of Magnetism: Origin of Magnetism, Magnetic moment, Magnetization. Susceptibility, Langevin Diamagnetic Susceptibility, Paramagnetic Susceptibility, Curie Weiss Law, Different kind of Magnetism: Dia, Para, Ferro, Antiferro, Ferri, Superpara, Nano-magnetism, Dielectric Properties: Polarization, Ferroelectric behavior.

Reference Books:

1- Introduction to Solid State Physics: Charles Kittle (Wiley)
2- Introduction to Nanomaterials and Devices : Omar Manasreh (Wiley)
3- Nanostructures and Nanomaterials: Guozhong Cao & Ying Wang (World Scientific)

<u>MTN1-03 : Properties of Nanomaterials</u>

TEACHING PLAN

S.No.	Title	Period	Teacher's Name
1	**Introduction:** Classifications of Nanomaterials : 2D, 1D and 0D systems	02	**Dr. Shahab Ahmad**
2	Role of Size on nanomaterial's properties: Thermal	02	-do-
3	Role of Size on nanomaterial's properties: Optical and Electronic	02	-do-
4	**Electronic Properties:** Classification of Materials: Metal, Semiconductor, Insulator, Band Structures	02	-do-
5	Mobility, Resistivity, Relaxation time	02	-do-
6	Hall effect: Hall voltage, Hall mobility, Hall Coefficient	02	-do-
7	Generation and Recombination: Radiative and Non-Radiative recombination, Net recombination rate equation, excess minority lifetime	02	-do-
8	**Optical Properties:** Optical Absorption and Transmission	02	-do-
9	Photoluminescence, Fluorescence, Phosphorescence, Excitons: Properties and Types of Excitons	02	-do-
10	Basic concepts of Photoconductivity	02	-do-
11	Electroluminescence in Fluorescent and Phosphorescent materials	02	-do-
12	**Confinement and Transport in nanostructure:** Density of States of Quantum Wells, Wires and Dots	02	-do-
13	Conductance formula for nanostructures	02	-do-
14	Quantized conductance	02	-do-
15	Ballistic transport, Coulomb blockade	02	-do-
16	**Magnetic Properties:** Fundamentals of Magnetism	02	-do-
17	Susceptibility, Langevin Diamagnetic Susceptibility, Paramagnetic Susceptibility, Curie Weiss Law	02	-do-
18	Different kind of Magnetism	02	-do-
19	Nano-magnetism	02	-do-
20	Dielectric Properties: Polarization, Ferroelectric behavior	02	-do-
		Total = 40 h	

M. Tech. Nanotechnology

Semester-I

MTN1-04 :Foundations in Micro & Nano-systems

Unit-I: Basic of Micro & Nano device

Moore's Laws, Carbon nanotube based transistor and its advancement, Clean Room, Clean Rooms Processing Methods, Thermal Oxidation, Chemical Etching (wet and dry), Plasma Etching (plasma physics, surface chemical reactions), Metallization, micromechanical process: bulk micromachining and surface micromachining techniques.

Unit-II: Semiconductor Processes and Techniques

Semiconductor substrates: Czochralski growth, float zone growth, wafer preparation and shaping, chemical cleaning, Resistivity, Thin film processes (thermal evaporation, chemical vapor deposition).

Unit-III: Measurement Technique

Contact resistance, mobility, carrier life-time and IV-CV measurement techniques, Test structures for technology characterization, Analysis of surfaces, interfaces, thin films, Use of silicon dioxide, polymers, and glass

Unit-IV: Processes for packaging techniques

Wafer-level bonding and packaging techniques; Flip-chip bonding, vacuum and hermetic packaging, micro-fluidic device packaging, LTCC technology, materials, LTCC process steps, bonding and packaging; Reliability and residual stress issues.

Reference Books:

1. Fabrication Engineering at the Micro- (OXFORD and Nanoscale : Stephen A. Campbell UNIVERSITY PRESS)
2. MICROSYSTEM DESIGN Academic : Stephen D. Senturia(Kluwer Publishers)
3. Fundamentals of Semiconductor (WILEY) Fabrication : Gary S. May & Simon M. Sze

MTN1-04 :Foundations in Micro & Nano-systems

TEACHING PLAN

S.No.	Title	Period	Teacher`s Name
1	Moore's Laws, Carbon nanotube based transistor and its advancement	02	**Dr. Prabhash Mishra**
2	Clean Room	02	-do-
3	Clean Rooms Processing Methods	02	-do-
4	Thermal Oxidation, Chemical Etching (wet and dry),	02	-do-
5	Plasma Etching (plasma physics, surface chemical reactions),	02	-do-
6	Metallization	02	-do-
7	micromechanical process: bulk micromachining and surface micromachining techniques.	04	-do-
8	Semiconductor substrates: Czochralski growth, float zone growth,	04	-do-
9	wafer preparation and shaping, chemical cleaning	02	-do-
10	Resistivity,	02	-do-
11	Thin film processes (thermal evaporation, chemical vapor deposition).	02	-do-
12	Contact resistance, mobility, carrier life-time and IV-CV measurement techniques,	02	-do-
13	Test structures for technology characterization, Analysis of surfaces, interfaces	04	-do-
14	thin films, Use of silicon dioxide, polymers, and glass	02	-do-
15	Wafer-level bonding and packaging techniques	02	-do-
16	Flip-chip bonding, vacuum and hermetic packaging, micro-fluidic device packaging	02	-do-
17	LTCC technology, materials, LTCC process steps, bonding and packaging; Reliability and residual stress issues.	02	-do-
		Total = 40 h	

M. Tech. Nanotechnology

Semester-I

MTN1-05 :Synthesis of Nanomaterials

Unit-I: Vacuum Technology

Vacuum principles: Basic terms and concepts; Continuum and Kinetic gas theory; Pressure ranges; Basic concepts, mean free path and its importance, vaccum ranges, flow regimes, Low vaccum pump (rotary pump). Introduction to pressure gauges: Working principle, advantages and disadvantages of Pirani and Penning Gauges

Unit-II: 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 techniques for production of Nano-structures including ultra-thin films and multilayer by: (a) Laser Ablation technique, (b) Arc Discharge technique and (c) Mechanical Milling

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

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

Unit-IV: Chemical Methods of Synthesis of Nanomaterials

Solution growth techniques of 1D-2D nano-structures: Synthesis of metallic, semiconducting nanoparticles, Solid, Liquid Phase and Gas Phase Synthesis of Nanomaterials: – Vapor (or solution) – liquid – solid (VLS or SLS) growth, Sol-gel method.

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 naonmaterials - Leon L. Shaw (editor).
4. Handbook of Nanotechnology, Bharat Bhushan, Springer.

MTN1-05 :Synthesis of Nanomaterials

TEACHING PLAN

S.No.	Title	Period	Teacher`s Name
1	**Vacuum principles**: Basic terms and concepts; Continuum and Kinetic gas theory; Pressure ranges	05	**Dr. Samina Husain**
2	**Vaccum technology:** Basic concepts, mean free path and its importance, vaccum ranges, flow regimes, Low vaccum pump (rotary pump).	04	-do-
3	**High vaccum pumps:** Constructions, working principles advantages and disadvantages of Diffusion, turbo-molecular, Ion and sorption pump.	04	-do-
4	**Introduction to pressure gauges:** Working principle, advantages and disadvantages of Pirani and Penning Gauges.	02	-do-
5	M**ethods of synthesizing Nano-materials:** Principles and relative merits of Laser Ablation, Arc discharge, Mechanical milling techniques.	03	-do-
6	**Introduction** to Nanoscience and Nanomaterials, Quantum confinement concept, synthesis of Nano structured materials, top down v/s bottom up approach and Nanofabrication techniques.	04	
7	**Physio-Chemical method of synthesis:** CVD with its different types including APCVD, LPCVD, PECVD. CVD techniques & Epitaxial techniques.	06	-do-
8	**Working principle**, conditions, operation and control mechanism of epitaxial grown films using MOCVD and MBE. Introduction to Sputtering method and Langmuir-Blodgett technique.	06	-do-
9	**Chemical method of synthesis of nanomaterials:** VLS growth, Sol-gel method and Spray pyrolysis.	06	-do-
		Total = 40 hrs.	

M. Tech. Nanotechnology

Semester-I

MTN1-06 : Quantum Theory and Modelling of Nanostructures

Unit-I: Quantum Mechanics and its applications
Review of the Origin of Quantum Mechanics-Plank's Quantum Hypothesis, Photon Nature of Light, de Broglie Waves and Wave- Particle Duality, Heisenberg's Uncertainty Principle. Postulates of quantum mechanics. Schordinger wave equation. Born's interpretation of wave function.

Unit-II: Bound states & quantum tunneling
Free particle - Momentum eigen functions, Energy levels of a particle – Infinite square well in one, two, and three dimensions - Density of states – Confined carriers - Electron wave propagation in devices - Quantum confinement - Penetration of a barrier – Tunnel effect - Basic principles of a few effective devices – Resonant tunnel diode, Superlattice , Quantum wire and Dot. Time development of the wave function - Time evolution operator - Schrodinger, Heisenberg, and Interaction pictures of quantum dynamics - Time evolution - Free particle wave packet, One-dimensional harmonic oscillator , Two-state quantum systems.

Unit-III: Numerical Methods
Application on elementary numerical methods (e.g., Taylor-series summations, roots of equations, roots of polynomials, systems of linear and nonlinear algebraic equations, integration). Applications in nanotechnology engineering. Finite Difference Time-Domain Method: Optical Responses, advantage & disadvantage, Practical implementation, Numerical examples. Finite element method: Introduction, Matrix form of the problem, Various types of finite element methods, Approximation of elliptic problems, Piecewise polynomial approach, One dimensional model problem. Numerical schemes for nonlinear systems. Basic modelling and simulation. Relevant applications: optical, thermal, mechanical, and fluidic, and nanoscale devices.

Unit-IV: Advanced modeling techniques
Molecular Dynamics; Monte Carlo Methods; Computations of Phase Transition under Confinement; General Basis for predicting physical properties of nanocrystals and large clusters; Quantum Confined Systems & computational techniques; 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.

Reference Books:

1. Franz Schwabi : Quantum Mechanics
2. A. K. Ghatak and S. Lokanathan: Quantum Mechanics
3. Mathematical Methods in the Physical Sciences, Mary L. Boas.
5. Finite Element Methods for Partial Differential Equations, Endre Suli.
6. Introduction to the Finite Element Method, J. N. Reddy.
7. Handbook of Theoretical and Computational Nanotechnology, M. Rieth and W. Schommers

MTN1-06 : Quantum Theory and Modelling of Nanostructures

TEACHING PLAN

S.No.	Title	Period	Teacher`s Name
1	**Quantum Mechanics and its applications:** Review of the Origin of Quantum Mechanics-Plank's Quantum Hypothesis.	02	**Dr. A K Hafiz**
2	Photon Nature of Light, de Broglie Waves and Wave-Particle Duality, Heisenberg's Uncertainty Principle.	02	-do-
3	Postulates of quantum mechanics. Schordinger wave equation. Born's interpretation of wave function.	02	-do-
4	**Bound states & quantum tunneling:** Free particle - Momentum eigen functions, Energy levels of a particle	02	-do-
5	Infinite square well in one, two, and three dimensions	02	-do-
6	Density of states. Confined carriers. Electron wave propagation in devices.	02	-do-
7	Quantum confinement. Penetration of a barrier. Tunnel effect.	02	-do-
8	Basic principles of a few effective devices. Resonant tunnel diode, Superlattice , Quantum wire and Dot.	02	-do-
9	Time development of the wave function. Time evolution operator. Schrodinger, Heisenberg, and Interaction pictures of quantum dynamics. Time evolution. Free particle wave packet,	02	-do-
10	One-dimensional harmonic oscillator, Two-state	02	-do-

	quantum systems.		
11	**Numerical Methods:** Application on elementary numerical methods (e.g., Taylor-series summations, roots of equations, roots of polynomials, systems of linear and nonlinear algebraic equations, integration).	02	-do-
12	Applications in nanotechnology engineering. Finite Difference Time-Domain Method: Optical Responses, advantage & disadvantage, Practical implementation, Numerical examples.	02	-do-
13	Finite element method: Introduction, Matrix form of the problem, Various types of finite element methods, Approximation of elliptic problems, Piecewise polynomial approach, One dimensional model problem.	02	-do-
14	Numerical schemes for nonlinear systems. Basic modelling and simulation.	02	-do-
15	Relevant applications: optical, thermal, mechanical, and fluidic, and nanoscale devices.	02	-do-
16	**Advanced modeling techniques:** Molecular Dynamics. Monte Carlo Methods. Computations of Phase Transition under Confinement.	02	-do-
17	General Basis for predicting physical properties of nanocrystals and large clusters. Quantum Confined Systems & computational techniques.	02	-do-
18	Computational Electrodynamics Methods. Large Scale Electronic Transport Calculations.	02	-do-
19	Density Functional Calculations in Carbon Nanotubes. Time Dependent Density Functional Theory.	02	-do-
20	Computational Study of Nanotubes; Excited State Properties (GW, BSE); Computing Mechanical Properties and Modeling Growth.	02	-do-
		Total = 40 h	

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

M.Tech (Nanotechnology)

Course of Study and Scheme of Examination

SECOND SEMESTER

Course No.	Subjects	CREDITS	Periods per week			Distribution of Marks			
			L	T	P	Mid Semester Evaluation		End Semester Exams	Total
						CWS	MST		
MTN 2-01	MEMS/NEMS and Sensors Technology	4	3	1	-	10	30	60	100
MTN 2-02	Characterization of Nanomaterials	4	3	1	-	10	30	60	100
MTN 2-03	Surface Engineering for Nanotechnology	4	3	1	-	10	30	60	100
MTN 2-04	Introduction to Nanophotonics	4	3	1	-	10	30	60	100
MTN 2-05	Nanomaterials For Energy Applications	4	3	1	-	10	30	60	100
MTN 2-06	Nanocomposite Materials	4	3	1	-	10	30	60	100
	Total Credits	**24**	**18**	**6**		**60**	**180**	**360**	**600**

CWS – Class Work Sessional

MST – Monthly Sessional Tests

M. Tech. Nanotechnology
Semester-II

MTN2-01 : MEMS/NEMS and Sensors Technology

Unit-I: Basic of MEMS/NEMS devices
Overview of MEMS, NEMS and Microsystems, Photoresist, Nature of photoresist, Photolithography, Next generation lithography techniques, deep-UV, e-beam, dip-pen, nano-imprint, extreme-UV, X-ray. DRIE and LIGA process. Micro/Nano-system design principles; MEMS/NEMS simulation and design Tools.

Unit-II: Sensors Fundamentals and Characteristics
Sensors, Signals and Systems; Classification of sensors, Units of Measurements, Sensor Characteristics, sensors types, classification of semiconductor sensors.

Unit-III: Semiconductor Sensors
Mechanical sensor, Acoustic sensors, thermal sensors, IR sensors, bolometer, FPA and their applications, Chemical sensors, Bio Sensors, Interaction to gaseous species at semiconductor surfaces, FET devices for Gas sensing.

Unit-IV: Trends in MEMS and nano-devices technologies.

Reference Books:

1. Semiconductor Sensors : Ed. S. M. Sze, John Wiley & sons.
2. NANO : The Essentials :T Pradeep, Tata McGraw-Hill Publishing
3. Sensors: A Comprehensive Survey (Micro and Nanosensors Technology/Trends in Sensor Markets). : Hans Meixner
4. Introduction to Nanosensors : Larry Nagahara,Nongjian Tao,

(Nanostructure Science and Technology) :Thomas Thundat.

MTN2-01 : MEMS/NEMS and Sensors Technology

TEACHING PLAN

S.No.	Title	Period	Teacher`s Name
1	Overview of MEMS, NEMS and Microsystems	04	**Dr. Prabhash Mishra**
2	Photoresist, Nature of photoresist.	02	-do-
3	Photolithography	02	-do-
4	Next generation lithography techniques, deep-UV, e-beam, dip-pen, nano-imprint, extreme-UV, X-ray.	02	-do-
5	DRIE and LIGA process	02	-do-
6	Micro/Nano-system design principles; MEMS/NEMS simulation and design Tools,	02	-do-
7	Sensors, Signals and Systems	02	-do-
8	Classification of sensors, Units of Measurement	02	-do-
9	Sensor Characteristics sensors types, classification of semiconductor sensors.	02	-do-
10	Mechanical sensor	02	-do-
11	Acoustic sensors	02	-do-
12	thermal sensors	02	-do-
13	IR sensors, bolometer	02	-do-
14	FPA and their applications	02	-do-
15	Chemical sensors	02	-do-
16	Bio-Sensors	02	-do-
17	Interaction to gaseous species at semiconductor surfaces, FET devices for Gas sensing.	02	-do-
18	Trends in MEMS and nano-devices technologies.	04	-do-
		Total = 40 h	

M. Tech. Nanotechnology

Semester-II

MTN2-02 : Characterization of Nanomaterials

Unit-I: Lattice Dynamics and vibrational spectroscopy
Phonon dispersion relation in 1D monoatomic solids, Phonon dispersion in 1D Diatomic solids, Raman effect, Theory of Raman scattering, Stokes and anti-stokes analysis, IR spectroscopy, analysis of Raman spectra in Graphite, Graphene, and Carbon Nanotubes.

Unit-II: Scanning Electron microscopy (SEM)
Some Fundamental Properties of Electrons, Resolution and Abbe's Equation, Basic Principle, Interaction of Electron with Samples: Secondary Electrons, Backscattered Electrons, Characteristic X-rays, Auger Electrons, and Cathodoluminescence, Configuration of Scanning Electron Microscopes, Electron Sources: The Physics of Different Electron Sources: Field Emission Guns, Lanthanum Hexaboride Gun, Tungsten Electron Guns, Comparison of Guns Electron. Lenses Condenser Lenses, Objective Lenses, Column Parameters, Aperture, Stigmation, Depth of Field, Image Formation, Signal Generation, Scanning Coils, Secondary Electron Detectors Specimen Composition, Specimen Topography, Specimen Magnification, Vacuum System: Mechanical Pumps, Diffusion Pumps, Ion Pumps, Turbo Pumps. Specimen Preparation: Metal Coating. Limitations of the SEM, Comparison with TEM.

Unit-III: Transmission Electron Microscopy (TEM) and SPM
Introduction, Electron as a source, resolution, types of electron Gun, Light matter interaction, different components of TEM, comparison with Optical microscope, Bright field imaging, dark field imaging, SAED pattern imaging. Sample preparation (Powder, liquid and bulk), Image analysis of TEM micrographs.

Unit-IV: XRD and SPM
Waves in crystals, diffraction by a discrete lattice**,** Wave vectors, Mathematics of diffraction, Laue method, Effect of thermal vibration, effect of different types of atoms on the diffraction pattern, Geometrical construction for diffraction, Powder method, working principle of XRD, XRD spectra analysis. Working principle of AFM and its image analysis, Working principle of STM and its image analysis

Reference Books:

1. Transmission Electron Microscopy, A textbook for Materials Science by David B. Williams and C. Barry Carter.
2. Scanning Electron Microscopy: Physics of image formation and Microanalysis by Ludwig Reimer.

3. Introductory Rama Spectroscopy edited by John Ferraro.
4. Fundamentals of Fourier Transform Infrared Spectroscopy by Brian C. Smith, 2nd Edition.

MTN2-02 : Characterization of Nanomaterials

TEACHING PLAN

S.No.	Title	Period	Teacher`s Name
1	Phonon dispersion in 1D monoatomic solids	02	**Prof. S.S. Islam**
2	Phonon dispersion in 1D Diatomic solids	02	-do-
3	Raman effect, Theory of Raman scattering, Stokes and anti-stokes analysis	02	-do-
4	IR spectroscopy	02	-do-
5	Analysis of Raman spectra in Graphite, Graphene, and Carbon Nanotubes.	02	-do-
6	Some Fundamental Properties of Electrons, Resolution and Abbe's Equation, Basic Principle, Interaction of Electron with Samples: Secondary Electrons, Backscattered Electrons, Characteristic X-rays, Auger Electrons, and Cathodoluminescence	02	-do-
7	Configuration of Scanning Electron Microscopes, Electron Sources: The Physics of Different Electron Sources: Field Emission Guns, Lanthanum Hexaboride Gun, Tungsten Electron Guns, Comparison of Guns Electron.	02	-do-
8	Vacuum System: Mechanical Pumps, Diffusion Pumps, Ion Pumps, Turbo Pumps.	02	-do-
9	Lenses Condenser Lenses, Objective Lenses, Column Parameters, Aperture, Stigmation, Depth of Field, Image Formation, Signal Generation, Scanning Coils, Secondary Electron Detectors Specimen Composition, Specimen Topography, Specimen Magnification	02	-do-
10	Specimen Preparation: Metal Coating. Limitations of the SEM, Comparison with TEM.	02	-do-
11	Introduction, Electron as a source, resolution, types of electron Gun, Light matter interaction,	02	-do-
12	different components of TEM, comparison with Optical microscope, Bright field imaging, dark field imaging,	02	-do-
13	SAED pattern imaging.	02	-do-
14	Sample preparation (Powder, liquid and bulk),	02	-do-
15	Image analysis of TEM micrographs	02	-do-
16	Waves in crystals, diffraction by a discrete lattice**,** Wave vectors, Mathematics of diffraction, Laue method	02	-do-

17	Effect of thermal vibration, effect of different types of atoms on the diffraction pattern	02	-do-
18	Geometrical construction for diffraction, Powder method, working principle of XRD, XRD spectra analysis.	02	-do-
19	Working principle of AFM and its image analysis	02	-do-
20	Working principle of STM and its image analysis	02	-do-
		Total = 40 h	

M. Tech. Nanotechnology

Semester-II

MTN2-03: Surface Engineering for Nanotechnology

Unit-I: Introduction to Surfaces

Surfaces and Interfaces – Importance of Surfaces in Nano Regime – Thermodynamics of surfaces – surface energy – Surface and interfacial tension and measurement– contact angle and wetting –Review of Surface Characterization Techniques. Adhesion and its importance – Adhesion vs cohesion

Unit-II: Colloidal Nanoscience

Introduction to colloidal material, surface properties, origin of colloidal particles, preparation & characterization of colloidal particles. Applications of super hydrophilic hydrophobic surfaces, self-cleaning surfaces.Surface viscosity.

Unit-III: Processes at Solid Surfaces

Adsorption – Physisorption and Chemisorption – Adsorption isotherms (Langmuir and BET) – Reaction Mechanism (Langmuir-Hinshelwood and Eley-Rideal) – Sticking Probability – Morphology in Catalysis– Active sites in catalysis & determination – porous materials and supported catalyst – spillover and reverse spillover, photoexcited charge carrier transfer and recombination; surface structure and particle size-induced band bending. Surface and electronic properties (-Zeta Potential) of surface.

Unit-IV: Surfaces in Multidisciplinary Applications

Environmental applications: waste water treatment (Nano-photocatalysis) involving degradation of organic pollutants, microbes and air treatment; antimicrobial surfaces, reduction of CO_2. and water splitting using TiO_2 nanoparticles; cleaning properties of nano-titania.

Reference Books:

1. Peter J. Blau, Friction Scienceand Technology- From concepts to applications, Second Edition, CRC Press, Boca Raton, 2009
2. Chemistry of Nanomaterials: Synthesis, properties and applications, CNR Rao et. al.(2004)
3. Nanostructured Materials and Nanotechnology – II, Eds. Sanjay Mathur and Mrityunjay Singh, Willey, 2008.

MTN2-03: Surface Engineering for Nanotechnology

TEACHING PLAN

S.No.	Title	Period	Teacher`s Name
1	**Introduction to Surfaces:** Surfaces and Interfaces – Importance of Surfaces in Nano Regime	02	**Dr. Manika Khanuja**
2	Thermodynamics of surfaces – surface energy	02	-do-
3	Surface and interfacial tension and measurement– contact angle and wetting	02	-do-
4	Review of Surface Characterization Techniques	02	-do-
5	Adhesion and its importance – Adhesion vs cohesion	02	-do-
6	**Colloidal Nanoscience**: Introduction to colloidal material, surface properties.	02	-do-
7	Origin of colloidal particles, preparation & characterization of colloidal particles.	02	-do-
8	Applications of super hydrophilic hydrophobic surfaces, self-cleaning surfaces.Surface viscosity.	02	-do-
9	**Processes at Solid Surfaces:** Adsorption – Physisorption and Chemisorption.	02	-do-
10	Adsorption isotherms (Langmuir and BET).	02	-do-
11	Reaction Mechanism (Langmuir-Hinshelwood and Eley-Rideal)- Sticking Probability.	02	-do-
12	Morphology in Catalysis– Active sites in catalysis	02	-do-
13	Determination – porous materials and supported catalyst – spillover and reverse spillover.	02	-do-
14	Photoexcited charge carrier transfer and recombination	02	-do-
15	Surface structure and particle size-induced band bending.	02	-do-
16	Surface and electronic properties (-Zeta Potential) of surface.	02	-do-
17	**Surfaces in Multidisciplinary Applications:** Environmental applications: waste water treatment (Nano-photocatalysis).	02	-do-
18	Degradation of organic pollutants, microbes and air treatment; antimicrobial surfaces.	02	-do-
19	Reduction of CO_2. and water splitting using TiO_2 nanoparticles.	02	-do-
20	Cleaning properties of nano-titania.	02	-do-
		Total = 40 h	

M. Tech. Nanotechnology
Semester-II

MTN2-04: Introduction to Nanophotonics

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).

MTN2-04: Introduction to Nanophotonics

TEACHING PLAN

S.No.	Title	Period	Teacher`s Name
1	**Concepts for Nanophotonics:** Comparison between photons and electrons: free space propagation and confinement. Concept of Photonic Bandgap. Analogy between Photonic and Electronic Bandgap.	02	**Dr. A K Hafiz**
2	Propagation of electromagnetic waves in bulk, across interface and across nanofilm.	02	-do-
3	Concept of Optical modes, Group velocity, Dispersion characteristics and group velocity dispersion associated with propagating electromagnetic fields.	02	-do-
4	Photons inside periodic structures.	02	-do-
5	Bloch modes: Dynamics of Bloch modes, Coupled mode theory.	02	-do-
6	**Optical nanostructures and quantum confinement**: One-dimensional confinement: quantum wells, two-dimensional confinement: quantum wires, and three-dimensional confinement: quantum dots.	02	-do-
7	Optical properties in confined structures.	02	-do-
8	Interaction of electromagnetic waves with nanoparticles (0-D); nanotubes, nanorods and nanowires (1-D).	02	-do-
9	Interaction of electromagnetic waves with Nanofilm, nanolayers and nanocoatings (2-D).	02	-do-
10	Optical response of nanoporous materials: Bruggeman's effective index method.	02	-do-
11	**Photonic Crystals:** One-, two-, and three-dimensional photonic crystals.	02	-do-
12	Properties of photonic bandgap. Defects in photonic crystals and concept of microcavity.	02	-do-
13	Fabrication technique and challenges for photonic crystals.	02	-do-
14	Photonic wave guides, Photonic Crystal Fibers, Quantum-well laser, QWID. Biophotonic applications.	02	-do-
15	Photonic crystal based mirrors and omni-directional reflectors. Optical sensing application.	02	-do-

16	**New approaches in Nanophotonics:** Near Field Optics. Apertureless near field optics.	02	-do-
17	Near field scanning optical microscopy (NSOM or SNOM).	02	-do-
18	SNOM based detection of plasmonic energy transport.	02	-do-
19	SNOM based visualization of waveguide structures.SNOM in nanolithography.	02	-do-
20	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.	02	-do-
		Total = 40 h	

M. Tech. Nanotechnology

Semester-II

MTN2-05: Nanomaterials for Energy Applications

Unit-I: First Generation Solar Cells

Introduction to photovoltaic (PV) systems, Solar energy potential for photovoltaics, solar radiation and spectrum of sun, Photovoltaics effect, First Generation of Solar Cells: Single crystalline Si-solar cells, basic structure and characteristics, fabrication of p-n junction, Testing of Solar cell.

Unit-II: Second Generation Solar Cells

Thin film silicon solar cells, Solar cell arrays, PV modules, Tandem Solar cells, Thin film PV cell fabrication: Various techniques of deposition, Semiconductors nanoparticles for PV devices, III-V and II-VI Solar materials.

Unit-III: Third Generation Solar Cells

Emerging new Solar cell technologies: dye sensitized solar cells, Perovskite solar cells: Crystal structure, Fabrication: Planar and Mesoporous TiO_2 nanoparticles based perovskite solar cells. Organic/plastic/flexible solar cells, polymer nanocomposites for solar cells, device fabrication, spin coating and characterization.

Unit-IV: Energy Storage: Li-ion Batteries and Supercapacitors

Overview of Lithium-ion Battery, Components of Li-ion Battery; Electrodes, Electrolytes and Interphases, Reaction Mechanism of Lithium-ion Batteries, Basic Characteristics of Lithium-ion Batteries, Capacity, C-rate, Electrochemical Characterizations: Cyclo-voltammetry, Charge and Discharge Characteristics, Application of Nanomaterials in Li-ion batteries. Overview of Supercapacitors, Components and Electrodes, Working mechanism of supercapacitors, Electrochemical Characterizations: Cyclo-voltammetry, Charge and Discharge Characteristics, Application of Nanomaterials in Supercapacitors.

Reference Books:

1- Advanced Silicon Materials for Photovoltaics Applications, Editor: Sergio Pizzini, Wiley
2- Photovoltaic Solar Energy: From Fundamentals to Applications, Editors: Angèle Reinders, Pierre Verlinden, Wilfried Sark and Alexandre Freundlich, 2017 John Wiley & Sons, Ltd.
3- Fundamentals and Applications of Li-ion Batteries in Electric Drive Vehicles, Jiuchun Jiang and Caiping Zhang, 2015 John Wiley & Sons, Ltd.

<u>MTN2-05: Nanomaterials for Energy Applications</u>

TEACHING PLAN

S.No.	Title	Period	Teacher`s Name
1	**First Generation Solar Cells:** Introduction to photovoltaic (PV) systems	02	**Dr. Shahab Ahmad**
2	Solar radiation and spectrum of sun light, Photovoltaics effect, First Generation of Solar Cells	02	-do-
3	Single crystalline Si-solar cells, basic structure and characteristics,	02	-do-
4	fabrication of p-n junction, Testing of Solar cells	02	-do-
5	**Second Generation Solar Cells:** Thin film silicon solar cells	02	-do-
6	Solar cell arrays, PV modules, Tandem Solar cells	02	-do-
7	Thin film PV cell fabrication: Various techniques of deposition	02	-do-
8	Semiconductors nanoparticles for PV devices, III-V and II-VI Solar materials.	02	-do-
9	**Third Generation Solar Cells:** Emerging new Solar cell technologies: Dye Sensitized solar cells	02	-do-
10	Perovskite solar cells: Crystal structure, Fabrication of planar and Mesoporous TiO_2 configurations.	02	-do-
11	Organic/plastic/flexible solar cells, polymer nanocomposites for solar cells	02	-do-
12	device fabrication, spin coating and characterization, Light Emitting Diodes	02	-do-
13	**Energy Storage-Li-ion Battery:** Overview of Lithium-ion Battery, Components of Li-ion Battery, Electrodes, Electrolytes and Interphases	02	-do-
14	Reaction Mechanism of Lithium-ion Batteries, Basic Characteristics of Lithium-ion Batteries, C-rate	02	-do-
15	Cyclo-voltammetry, Charge and Discharge Characteristics	02	-do-
16	Application of Nanomaterials in Li-ion batteries.	02	-do-
17	**Supercapacitors:** Overview of Supercapacitors, Components and Electrodes	02	-do-
18	Working mechanism of supercapacitors, Cyclo-voltammetry, Charge and Discharge Characteristics	02	-do-
19	Applications of Nanomaterials in Supercapacitors	02	-do-
20	**Revision, Doubts, Questions**	02	-do-
		Total = 40 h	

M. Tech. Nanotechnology
Semester-II

MTN2-06: Nanocomposite Materials

Unit-I: Introduction to Composite Materials
Classifications of Engineering Materials, Concept of composite materials, Matrix materials, Functions of a Matrix, Desired Properties of a Matrix, Polymer Matrix (Thermosets and Thermoplastics), Metal matrix, Ceramic matrix, Carbon Matrix, Glass Matrix etc. Types of Reinforcements/Fibers: Role and Selection or reinforcement materials, Types of fibres, Glass fibers, Carbon fibers, Aramid fibers , Metal fibers etc.

Unit-II: Various types of Composites
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, Advantages & limitations of Nanocomposites.

Unit-III: **Nanocomposite Materials**
Introduction, Types of nanocomposites – Polymer based, Metal based, Fabrication of Nanocomposites: Direct mixing, solution mixing, In-situ polymerization, other methods, Polymer/ Metal oxide nanocomposites, Polymer/CNTs, Polymer/Graphene based nanocomposites.

Unit-IV: **Applications of Nanocomposites**
Structural application and Functional application such as of Polymer based and metal based nanocomposites.

Reference Books:

1. Nanocomposites - Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun, Wiley-VCH, 2004.
2. Carbon Nanotubes for Polymer Reinforcement, Peng-Cheng Ma and Jang-Kyo Kim, CRC Press, Taylor and Francis Group, 2011.
3. Composite Materials, Deborah D. L. Chung, Springer, 2002.

MTN2-06: Nanocomposite Materials

TEACHING PLAN

S.No.	Title	Period	Teacher`s Name
1	**Introduction to Composite Materials:** Classifications of Engineering Materials, Concept of composite materials	02	**Dr. Samina Husain**
2	Matrix materials, Functions of a Matrix, Desired Properties of a Matrix, Polymer Matrix (Thermosets and Thermoplastics), Metal matrix, Ceramic matrix, Carbon Matrix, Glass Matrix etc.	06	-do-
3	**Types of Reinforcements/Fibers**: Role and Selection or reinforcement materials, Types of fibres, Glass fibers, Carbon fibers, Aramid fibers , Metal fibers etc.	04	-do-
4	**Various types of Composites** : 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)	06	-do-
5	**Classification based on reinforcements**: Fiber Reinforced Composites, Fiber Reinforced Polymer (FRP) Composites, Laminar Composites, Particulate Composites	04	-do-
6	Advantages & limitations of Nanocomposites.	02	-do-
7	**Nanocomposite Materials:** Introduction, Types of nanocomposites – Polymer based, Metal based	06	-do-
8	Fabrication of Nanocomposites: Direct mixing, solution mixing, In-situ polymerization, other methods, Polymer/ Metal oxide nanocomposites, Polymer/CNTs, Polymer/Graphene based nanocomposites.	06	-do-
9	**Applications of Nanocomposites:** Structural application and Functional application of Polymer based and metal based nanocomposites.	04	-do-
		Total = 40 hrs.	

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

M.Tech (Nanotechnology)

Course of Study and Scheme of Examination

THIRD SEMESTER

Course No.	Subjects	CREDITS	Periods per week			Distribution of Marks			
			L	T	P	Mid Semester Evaluation		End Semester Exams	Total
						CWS	MST		
P-01	Project Presentation Examination	24	-	-	-	-	-		600
	Total Credits	**24**							**600**

CWS – Class Work Sessional

MST – Monthly Sessional Tests

Centre for Nanoscience and Nanotechnology
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M.Tech (Nanotechnology)

Course of Study and Scheme of Examination

FOURTH SEMESTER

Course No.	Subjects	CREDITS	Periods per week			Distribution of Marks			
			L	T	P	Mid Semester Evaluation		End Semester Exams	Total
						CWS	MST		
P-02	Project Presentation Examination	24	-	-	-	-	-		600
	Total Credits	**24**							**600**

CWS – Class Work Sessional

MST – Monthly Sessional Tests

Semester-III

P-01: Project Presentation Examination

M.Tech students have to 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

M.Tech students have to 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.