SCHOOL OF ELECTRONICS ENGINEERING

M. Tech Nanotechnology

(M.Tech MNT)

Curriculum

(*2022-2023 admitted students*)

VISION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

Transforming life through excellence in education and research.

MISSION STATEMENT OF VELLORE INSTITUTE OFTECHNOLOGY

World class Education: Excellence in education, grounded in ethics and critical thinking, for improvement of life.

Cutting edge Research: An innovation ecosystem to extend knowledge and solve critical problems.

Impactful People: Happy, accountable, caring and effective workforce and students.

Rewarding Co-creations: Active collaboration with national & international industries & universities for productivity and economic development.

Service to Society: Service to the region and world through knowledge and compassion.

VISION STATEMENT OF THE SCHOOL OF ELECTRONICSENGINEERING

To be a leader by imparting in-depth knowledge in Electronics Engineering, nurturing engineers, technologists and researchers of highest competence, who would engage in sustainable development to cater the global needs of industry and society.

MISSION STATEMENT OF THE SCHOOL OF ELECTRONICS ENGINEERING

- Create and maintain an environment to excel in teaching, learning and applied research in the fields of electronics, communication engineering and allied disciplines which pioneer for sustainable growth.
- Equip our students with necessary knowledge and skills which enable them to be lifelong learners to solve practical problems and to improve the quality of human life.

M. Tech Nanotechnology

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

1. Graduates will be engineering practitioners and leaders, who would help solve industry’s technological problems.

2. Graduates will be engineering professionals, innovators or entrepreneurs engaged in technology development, technology deployment, or engineering system implementation in industry.

3. Graduates will function in their profession with social awareness and responsibility.

4. Graduates will interact with their peers in other disciplines in industry and society and contribute to the economic growth of the country.

5. Graduates will be successful in pursuing higher studies in engineering or management.

6. Graduates will pursue career paths in teaching or research.

M. Tech Nanotechnology

PROGRAMME OUTCOMES (POs)

PO_01: Having an ability to apply mathematics and science in engineering applications.

PO_02: Having an ability to design a component or a product applying all the relevant standards and with realistic constraints, including public health, safety, culture, society and environment

PO_03: Having an ability to design and conduct experiments, as well as to analyse and interpret data, and synthesis of information

PO_04: Having an ability to use techniques, skills, resources and modern engineering and IT tools necessary for engineering practice

PO_05: Having problem solving ability- to assess social issues (societal, health, safety, legal and cultural) and engineering problems

PO_06: Having adaptive thinking and adaptability in relation to environmental context and sustainable development

PO_07: Having a clear understanding of professional and ethical

responsibility

PO_08: Having a good cognitive load management skills related to project management and finance

M. Tech Nanotechnology

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Tech. (Nanotechnology) programme, graduates will be able to

PSO1: Evolving crucial understanding of Physics & Chemistry of solids, Quantum physics of nanostructures, Nano-electronics and Nano-photonics.

PSO2: Concentrating on specific skills on Synthesis of nanomaterials, thin film deposition and their characterization.

PSO3: Solve research gaps and provide solutions to socio-economic, and environmental problem.

Master of Technology in Nanotechnology

School of Electronics Engineering

Programme Credit Structure	Credits
Discipline Core Courses	24
Skill Enhancement Courses	05
Discipline Elective Courses	12
Open Elective Courses	03
Project/ Internship	26
Total Graded Credit Requirement	70

Discipline Core Courses — 24

		L	T	P	C
MNAT501L	Semiconductor Device Physics and Technology	3	0	0	3
MNAT502L	Physics and Chemistry of Solids	3	0	0	3
MNAT503L	Quantum Physics for Nanostructures	3	0	0	3
MNAT504L	Carbon Nanomaterials	3	0	0	3
MNAT505L	Synthesis of Nanomaterials and Thin Film Deposition	3	0	0	3
MNAT505P	Synthesis of Nanomaterials and Thin Film Deposition Lab	0	0	2	1
MNAT506L	Nanomaterial Characterization Techniques	3	0	0	3
MNAT506P	Nanomaterial Characterization Techniques Lab	0	0	2	1
MNAT507L	Nanoelectronics	3	0	0	3
MNAT507P	Nanoelectronics Lab	0	0	2	1

Skill Enhancement Courses — 05

MENG501P	Technical Report Writing	0	0	4	2
MSTS501P	Qualitative Skills Practice	0	0	3	1.5
MSTS502P	Quantitative Skills Practice	0	0	3	1.5

Discipline Elective Courses — 12

MNAT601L	MEMS to NEMS	3	0	0	3
MNAT602L	Nanosensors	3	0	0	3
MNAT603L	Nanophotonics	3	0	0	3
MNAT604L	Lithographic Techniques for Device Fabrication	3	0	0	3
MNAT605L	Plasmonics	3	0	0	3
MNAT606L	Nanomagnetism- Fundamentals and Applications	3	0	0	3
MNAT607L	Energy Technologies	3	0	0	3
MNAT608L	Spintronics	3	0	0	3
MNAT609L	Nanoelectronic Circuit Design	3	0	0	3

Open Elective Courses — 03

Engineering Disciplines | Social Sciences

Project and Internship — 26

MNAT696J	Study Oriented Project	02
MNAT697J	Design Project	02
MNAT698J	Internship I/ Dissertation I	10
MNAT699J	Internship II/ Dissertation II	12

Course Code	Course Title	L	T	P	C
MNAT501L	**Semiconductor Device Physics and Technology**	**3**	**0**	**0**	**3**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed to:

1. Make them understand the physics of semiconductor materials and devices.
2. Educate the working mechanism and design of optoelectronic devices.
3. Train them to solve bandgap models and design different semiconductor devices.

Course Outcome

Students will be able to:

1. Develop in-depth knowledge in semiconductor physics
2. Build the knowledge of mathematical model of various device fabrication processes
3. Construct in-depth knowledge of formation and properties of PN junctions
4. Develop the fundamentals of metal-semiconductor junctions
5. Understand the physics of optoelectronic devices
6. Understand the fabrication and characteristics of nanoscale MOSFETs
7. Apply the concepts and techniques to solve bandgap model equations and design varioussemiconductor devices.

Module:1	**Semiconductor Physics**	**10 hours**

Semiconductor Materials, Basic Crystal Structure, Directions and planes in crystal, Basic Crystal Growth Technique, Formation of Energy Bands, E-k structure, effective mass ellipsoid in Silicon, Intrinsic Carrier Concentration in thermal Equilibrium, Fermi-Dirac and Bose-Einstein Distribution, phonons in solids, Donors and Acceptors, Carrier Transport: Carrier Drift, Mobility and velocity saturation, Carrier Diffusion, Generation and Recombination Processes, Einstein Equation, Continuity Equation, Quantum Tunneling, High-Field Effects. Concept of Equilibrium, Non-equilibrium and Steady state, Excess Carriers, EHP creation by radiation, Carrier lifetime, Quasi-fermi levels

Module:2	**Device Process stages I**	**4 hours**

Device Process stages I: Mathematical models relevant to thermal diffusion and ion implantation and Annealing. Pattern transfer; Optical lithography, Photoresists, Alignment and exposure, Etching.

Module:3	**Device Process stages II**	**4 hours**

Mathematical models relevant to Deposition; Physical and chemical vapor deposition, Epitaxy. Process Integration: Device isolation, contacts metallization.

Module:4	**P-N Junction**	**8 hours**

Diode fabrication, Device physics: Thermal equilibrium, Internal electro-static fields and potentials, drift-diffusion equations. I-V Characteristics: Forward bias, reverse bias, Diode equation. Avalanche and Zener Breakdown mechanism, Capacitive effect: Junction and diffusion capacitance. DC, AC and transient analysis of Diodes, Linearly graded junctions, Varactor diode.

Module:5	**Metal-Semiconductor Contacts and Schottky Diodes**	**4 hours**

Metal-Semiconductor Junction diode Fabrication, Device Physics: Ideal MS contacts, Schottky diode-Electrostatics, I-V characteristics, DC, AC and transient analysis. Metal-Semiconductor contacts: Ohmic contacts, Schottky contacts, Tunnel contacts and Annealed and alloyed contacts.

Module:6	**Optoelectronic Diodes**	**4 hours**

Photodiode Fabrication, device Physics of p-n Junction Photodiodes, p-i-n Photo diodes. Principle of operation and fabrication technologies of Solar cell, LED and LASER diodes.

Module:7	**MOSFET**	**9 hours**
MOS capacitor, Band diagrams, C-V characteristics; Effect of metal work function, oxide and interface trapped charges. Threshold voltage. MOSFET device fabrication, MOSFET Physics: I-V characteristics, Sub-threshold region, Body effect, Capacitive effect, small and large signal model. Channel length modulation; Subthreshold current, Quantum mechanical effects in MOSFETs, Tunneling current Short Channel effects: Punch through, DIBL, Hot electron effect, mobility Degradation models, Leakage current.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Ben G. Streetman and Sanjay Banerjee, Solid State Electronic Devices, 2016, 7th Edition, Pearson Ed.
2.	S. M. Sze and Ming-Kwei Lee, Semiconductor Devices Physics and technology, 2013, John Wiley & Sons.
Reference Books	
1.	Grundmann and Marius, Physics of Semiconductors, Springer, 2010
2.	M. S. Tyagi, Introduction to semiconductor materials and devices, John Wiley & Sons, 2008.
3.	Campbell, Stephan, Fabrication Engineering at the Micro and Nanoscale, Oxford University Press, 2008.
4.	Robert F. Pierret, Semiconductor Device Fundamentals, Pearson Education, 2006.
5.	Richard C. Jaeger, Introduction to Microelectronic Fabrication, Prentice Hall, 2001.

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MNAT502L	**Physics and Chemistry of Solids**	**3**	**0**	**0**	**3**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed to:

1. Provide understanding of properties of materials from an atomistic view point, and to classify solids.
2. Outline the properties and structure of crystalline materials, various modes of bonding in solids with appropriate examples.
3. Render them about thermodynamics and statistical mechanics of solids.

Course Outcome

Students will be able to:

1. Understand knowledge on crystal structure and identify defects
2. Compare various types of atomic bonding in solids.
3. Classify materials and analyze their properties.
4. Understand thermodynamics and elementary statistical mechanics.

Module	Title	Hours
Module:1	**Structure of Matter**	**8 hours**
Crystal structure & Bonding- Crystals, Polycrystals, Symmetry, Unit cells, Bravais lattices, Crystallographic directions, Crystallographic planes, Miller indices, Bragg’s law, Single crystal and Powder X-ray diffraction.		
Module:2	**Imperfections in Solids**	**4 hours**
Imperfections of crystal structure –point defects, Grain boundaries, phase boundaries, Dislocations Screw, Edge and Mixed Dislocations		
Module:3	**Chemical Bonding**	**6 hours**
Atomic Structure - Types of bond: Metallic, Ionic, Covalent and van der Waals bond; Hybridization; H-bonding Molecular orbital theory for simple molecules.		
Module:4	**Classification of Solid Materials**	**5 hours**
Metals, Semiconductors, and Insulators: Fermi energy, Work function, Ionization potential, Electron affinity, Energy Band structure, Electronic conductivity and Thermal Conductivity		
Module:5	**Phonons**	**4 hours**
Lattice vibration, quantization of elastic waves, phonon momentum, and phonon heat capacity		
Module:6	**Magnetic and Optical properties of solids**	**8 hours**
Magnetic properties- Different kind of magnetism in nature: Dia, Para, Ferro, Antiferro, Ferri, Superpara; Optical Properties- Photoconductivity, Optical absorption, transmission, and emission, Photoluminescence, Fluorescence, Phosphorescence, Electroluminescence		
Module:7	**Introduction to Thermodynamics and Elementary Statistical Mechanics**	**8 hours**
The first and second laws of thermodynamics, Thermodynamic functions, enthalpy, entropy and Microstates, Gibb’s free energy, Endothermic and Exothermic reactions, Spontaneous and Non-Spontaneous reactions; Classical Statistical systems- Boltzmann statistics; Quantum statistical systems- Fermi- Dirac and Bose-Einstein Statistics		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Charles Kittel, Introduction to Solid State Physics, 2019, eighth Edition, John Wiley & Sons, ISBN-10: 8126578432

2.	H. Ibach and H. Lűth, Solid-State Physics: An Introduction to Principles of Material Science 2009, fourth edition, Springer
Reference Books	
1.	A.J. Dekker, Macmillan, Solid State Physics, 1969
2.	L. H. Van Vlack, Elements of materials science, Pearson Education, 2002
3.	Atkins Peter, Paula Julio, Physical Chemistry, Oxford University Press, 2008
4.	K. Huang, Chapman and Hall, Introduction to Statistical Physics, CRC, 2009
5.	Stephen Elliott & S. R. Elliott, The Physics and Chemistry of Solids, John Wiley & Sons, 1998.

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MNAT503L	Quantum Physics for Nanostructures	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objective:

The course is aimed to

1. Educate various concepts of quantum theory and its importance.
2. Make them understand the different quantum nanostructures and theirdensity of states.
3. Enable them to apply quantum theory to design nanoscale devices.

Course Outcomes:

Students will be able to:

1. Describe the basic concepts of quantum theory.
2. Explain the importance of Schrodinger wave equation & solve the related problems.
3. Apply the knowledge on quantum confinement effects.
4. Analyze dispersion relation of electron in solids.
5. Compare and determine the quantum nanostructures, such as quantum dots, nanowires and quantum wells with their density of states.
6. Elaborate the time-dependent perturbation and its applications.

Module	Title	Hours
Module :1	**Introduction**	**8 hours**
Importance of Quantum theory, Blackbody Radiation, Photoelectric Effect, Compton Effect, Wave-particles duality, de-Broglie Wavelengths, Wave function, Dynamical operators, Uncertainty principle, Quantum numbers and Hydrogen atom problem, Quantization Rules Pauli exclusion principle.		
Module:2	**Schrodinger equations and their formulation**	**8 hours**
Mathematical Tools of Quantum Mechanics, Hilbert Space and Wave Functions, Dirac Notation, Matrix Representation of Kets, Bras, and Operators, Matrix Representation of the Eigenvalue Problem, Postulates of Quantum Mechanics, Schrodinger time independent and time dependent wave equations.		
Module:3	**Potential Well, Potential Barrier and Tunnelling**	**6 hours**
One-Dimensional Potential well, Particle in 1D, 2D and 3D box, The Harmonic Oscillator, Rectangular Barrier, Concept of Tunneling, Reflectance, transmittance and tunnelling probability, Scanning tunnelling microscope, Numerical Solution of the Schrödinger Equation		
Module:4	**Theory of conduction in solids**	**4 hours**
Description of the theory of Conduction in Solids -Drude model, Nearly free electron model, Dispersion relation for electron.		
Module:5	**Electronic Band Structure**	**6 hours**
Periodic lattice, Brillouine zones, Periodic potential, Bloch Theorem, Kronig-Penny Potential and Electronic energy bands, direct and indirect gap semiconductors.		
Module:6	**Quantum Confinement and Density of States**	**5 hours**
Concept of Quantum Confinement, Quantum Dots, Quantum Well and Quantum Wires, Density of states in 3D, 2D, 1D and 0D solid, carrier concentration.		
Module:7	**Perturbation theory and Applications**	**6 hours**
Time-Independent Perturbation Theory, Nondegenerate and degenerate Perturbation Theory, Fine Structure and the Anomalous Zeeman Effect, 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.		

Module:8	**Contemporary Issues**			**2 hours**
			Total Lecture hours:	**` 45 hours**
Text Book(s)				
1	David J. Griffiths, Introduction to Quantum Mechanics, 2016, Cambridge India.			
2	Nouredine Zettili, Quantum Mechanics: Concepts and Applications, 2009, 2nd edition, Wiley.			
Reference Books				
1	A. F. J. Levi, Applied Quantum Mechanics, Second edition, Cambridge University Press, 2006.			
2	Richard L. Liboff, Introductory Quantum Mechanics, Fourth edition, Pearson Education Inc, India, 2003.			
3	A. Ghatak and S. Lokanathan, Quantum Mechanics–Theory & Applications, Macmillan India Limited, New Delhi, 2002.			
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.				
Recommended by Board of Studies	28-07-2022			
Approved by Academic Council	No. 67	Date	08-08-2022	

Course Code	Course Title	L	T	P	C
MNAT504L	**Carbon Nanomaterials**	**3**	**0**	**0**	**3**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed to:

1. Make the students understand the importance of carbon based nanostructured materials.
2. Study various carbon allotropes, their types, structure, properties and applications.
3. Emphasize other carbon based nanostructured materials such as nanocones, nanofibers, nanodiscs and nanodiamonds.

Course Outcome

Students will be able to:

1. Understand the importance of carbon based nanomaterials.
2. Develop the knowledge on synthesis, characterization and application of various carbon based nanomaterials such as fullerene, carbon nanotubes and graphene.
3. Understand the functionalization and applications of CNT & Graphene.
4. Compare the properties of other carbon based nanomaterials such as nanocones, nanofibers, nanodiscs and nanodiamonds.

Module	Title	Hours
Module:1	**Carbon Nanomaterials**	**2 hours**
Introduction to Carbon Nanomaterials, Carbon allotropes and their bonding between carbon atoms.		
Module:2	**Fullerene**	**6 hours**
Structure, Synthesis, Functionalization of fullerenes, Applications – Solar Cells, Hydrogen storage, Bio-applications.		
Module:3	**Carbon nanotubes**	**8 hours**
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.		
Module:4	**Functionalization and Applications of CNTs**	**8 hours**
Functionalization- Covalent, non-covalent, and biological; Applications - Energy storage: Batteries, Fuel Cells: H_2, Li storage, supercapacitors; Molecular electronics–Field emitting devices and Transistors, drug delivery, CNT based microscopy, Nanotube sensors.		
Module:5	**Graphene**	**7 hours**
Electronic band structure, Properties of Graphene: chemical, mechanical, electronic and thermal. Synthesis of Graphene – Exfoliation, Epitaxial, CVD, Hummer Method; Graphene Nanoribbon- synthesis.		
Module:6	**Functionalization and Applications of Graphene**	**6 hours**
Functionalization- Covalent, non-covalent Application of Graphene; Applications – Graphene MOSFET – Opening a Band gap, Spintronics, Solar cells, gas sensors, supercapacitors.		
Module:7	**Other Carbon based materials**	**6 hours**
Carbon Nanocomposite, Nanocones, Nanofibers, Nanodiscs and Nanodiamonds.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Yury Gogotsi, Volker Presser, Carbon Nanomaterials, Second edition, 2017, CRC

	Press, Taylor & Francis, United States.
2.	Jamie H. Warner, Franziska Schaffel, Mark Rummeli, AlicjaBachmatiuk, Graphene:Fundamentals and Emergent Applications, 2018, Elseiver Science.
Reference Books	
1.	Zhong Lin Wang, Nanowires and Nanobelts- Materials, Properties and Devices, Springer, 2006
2.	Thomas Webbester, Carbon Nanotube preparation and properties, CRC Press, 1997
3.	R Saito, G Dresselhaus, M S Dresselhaus, Physical Properties of Carbon Nanotubes, Imperial college press, 2004
4.	Yury Gogotsi, Volker Presser, Carbon nanomaterials, CRC Press, 2014
5.	CNR Rao and A Govindaraj, Nanotubes and Nanowires, RCS Nanoscience and Nanotechnology series, 2011
6.	Michael J. O'Connell, Carbon Nanotubes: Properties and Applications, CRC Taylor and Franci group, 2006.
7.	Mikhail I. Katsnelson, Graphene: Carbon in two dimensions, Cambridge University Press, 2012
8.	Fernando Langa, Jean-Francois Nierengarten, Fullerenes: Principles and Applications , RSC Publishing, 2007

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MNAT505L	Synthesis of Nanomaterials and Thin Film Deposition	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

The course is aimed to:

1. Make them understand the fabrication of nanostructures for advanced devices.
2. Provide and train the students about nanomaterial synthesis and thin film deposition techniques.

Course Outcome

Students will be able to:

1. Identify and understand various top-down and bottom-up approaches for nanomaterial synthesis.
2. Understand and apply vacuum technology for nanomaterial synthesis.
3. Describe various deposition techniques at the atomic and molecular level.
4. Develop knowledge about structure and properties of thin films.
5. Understand the advanced concept in various vapor deposition techniques

Module	Title	Hours
Module:1	Nanomaterial Synthesis - Top-Down Approach	6 hours
Physical methods- Inert gas condensation, aerosol method, Arc discharge, RF-plasma, Plasma arc technique, laser ablation, Gas-phase synthesis, Spray Pyrolysis, Ball Milling, Combustion		
Module:2	Nanomaterial Synthesis - Bottom-up approach	9 hours
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.		
Module:3	Vacuum technology	5 hours
Concept of different vacuum pumps - rotary, diffusion, Turbo molecular pump, Cryogenic-pump, Ti-sublimation pump; Concept of different gauges - pirani, penning, Pressure control.		
Module:4	Wafer Growth and Epitaxial Deposition	5 hours
Crystal Growth - CZ, Float zone technique; Basic Properties of different substrates (e.g. semiconductor, glass); Wafer cutting; Sources and related effects of various contamination; Wafer processing; Epitaxial growth- Growth kinetics of epitaxy, Doping, Growth modes.		
Module:5	Structure and properties of thin films	6 hours
Definition of thin films- Environment (Gas phase and plasma) for thin film deposition, Deposition parameters and their effects on film growth; Physical parameters for evaluation of thin films- Surface roughness; Density; Stress in thin films; Adhesion; Stoichiometry.		
Module:6	Physical vapor deposition (PVD) techniques	6 hours
Evaporation- Thermal evaporation, resistance evaporation, Electron beam evaporation, Ion vapor evaporation and Cathodic arc deposition; Molecular Beam Epitaxy; Sputtering- Glow discharge sputtering, Magnetron sputtering, Ion beam sputtering; Atomic layer deposition (ALD)-Importance of ALD technique.		
Module:7	Chemical vapor deposition techniques	6 hours
Fundamentals, Advantages and limitations of Chemical vapor deposition (CVD) techniques; Different kinds of CVD techniques- Metallorganic (MO) CVD, Photoassisted CVD, Thermally activated CVD, Plasma enhanced (RF, µ-Wave) CVD, Low pressure (LP) CVD, Atmospheric pressure (AP) CVD etc.		

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Guozhong Cao. Ed Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, 2011, World Scientific Series in Nanoscience and Nanotechnology.
2.	G.A. Ozin and A.C. Arsenault, Nanochemistry: A chemical approach to nanomaterials, 2009, 2nd Edition, Royal Society of Chemistry.
Reference Books	
1.	Bharat Bhushan, Handbook of Nanotechnology, Springer, 2005
2.	Hari Singh Nalwa, Handbook Of Nanostructured Biomaterials And Their Applications In Nanobiotechnology, Journal of Nanoscience and Nanotechnology, 2005.
3.	D.M. Hata, Introduction to Vacuum Technology, Prentice Hall New Jersey, 2007.
4.	K. Jousten, Handbook of Vacuum Technology, John Wiley and sons, Weinheim, 2008.
5.	S. Schmidt et al., CFx thin films deposited by high power impulse magnetron sputtering: synthesis and characterization Surf.Coat.Technol. 2011, 206, pp. 646-653.
6.	J. George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005.

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title		L	T	P	C
MNAT505P	**Synthesis of Nanomaterials and Thin Film Deposition Lab**		**0**	**0**	**2**	**1**
Pre-requisite	**NIL**	**Syllabus version**				
		1.0				

Course Objectives

The course is aimed to:

1. Make them understand the fabrication of nanostructures for advanced devices.
2. Provide and train the students about nanomaterial synthesis and thin film deposition techniques.

Course Outcome

Students will be able to:

1. Synthesize and deposit nanomaterials by various methods

Indicative Experiments

1.	Wet Chemical synthesis of Silver Quantum Dots - Effect of viscosity on the growth and its characterization by UV-Visible spectroscopy.	6 hours
2.	Synthesis of ZnO nanoparticles by wet chemical route and its optical band gap calculation.	6 hours
3.	Mie formalism of Optical absorption of Ag and Au nanoparticles for size estimation.	4 hours
4.	Calculation of d-spacing and crystallite size of Nanomaterials from X- ray diffraction data.	4 hours
5.	Thin film deposition using Electroplating technique and morphology characterization using Optical microscope.	3 hours
6.	Fabrication of thin films using Spin coating technique.	3 hours
7.	Fabrication of metal thin films on silicon/glass substrate using Metal evaporation Unit	4 hours
	Total Laboratory Hours	**30 hours**

Mode of Assessment: Continuous Assessment and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	**Course Title**	**L**	**T**	**P**	**C**
MNAT506L	**Nanomaterial Characterization Techniques**	**3**	**0**	**0**	**3**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed to:

1. Make them understand various Nanostructure characterization techniques.
2. Train the students on state-of-the-art metrology tools such as Scanning Probe Microscopes and optical spectroscopes.
3. Enable them to study the material's structure and properties that are probed and measured.

Course Outcome

Students will be able to:

1. Distinguish the conventional aspects of metrological tools.
2. Understand the working of various morphological techniques and selecting appropriate tools for their future research.
3. Determine the applications of various spectroscopic techniques.
4. Develop the knowledge of Scanning probe techniques for characterization.
5. Summarize the operation of optical and magnetic characterization techniques.

Module:1	**Introduction to Metrology**	**4 hours**
Concepts of Metrology- Accuracy, precision and reliability; Types of Errors - Systematic Errors and Random Errors, Statistical analysis of errors.		
Module:2	**Microscopy Techniques**	**8 hours**
Optical microscopy; Electron microscopy- Scanning Electron Microscopy, EDX, WDX; Transmission Electron Microscopy; EELS; SPM.		
Module:3	**Spectroscopy Techniques**	**9 hours**
UV-Vis Spectroscopy; Ellipsometer; XPS; XAS; XRD; Raman Spectroscopy - Surface-enhanced Raman Spectroscopy		
Module:4	**Scanning Tunneling Microscopy**	**8 hours**
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.		
Module:5	**Atomic Force Microscopy**	**7 hours**
Atomic Force Microscope - Modes of operation of AFM, Advanced Modes of AFM – Force Modulation, Conductive AFM, EFM, MFM, SCM.		
Module:6	**Near Field Scanning Optical Microscopy**	**5 hours**
Principles of operation, Different modes of operation, Spectroscopic Applications of NSOM.		
Module:7	**Magnetic Characterization**	**2 hours**
Principles, Components of SQUID systems, Vibrating Sample Magnetometer (VSM)		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	R.W. Cahn, E.M. Lifshitz, Concise Encyclopedia of Materials Characterization: Advances in Materials Sciences and Engineering,Elsevier, 2016.
2.	Yang Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons, 2013.

Reference Books

1.	Richard Leach, Fundamental Principles of Engineering Nanometrology, Elsevier, 2014.
2.	Mauro Sardela, Practical Materials Characterization, Springer, 2014.
3.	Ewen Smith, Geoffrey Dent, Modern Raman Spectroscopy: A Practical Approach, John Wiley & Sons, 2013.
4.	Nikodem Tomczak, Kuan Eng Johnson Goh, Scanning Probe Microscopy, World Scientific, 2011.
5.	Ernst Meyer, Hans J. Hug, Roland Bennewitz, Scanning Probe Microscopy: The Lab on a Tip, Springer Science & Business Media, 2013.
6.	Vladimir V. Tsukruk, Srikanth Singamaneni, Scanning Probe Microscopy of Soft Matter: Fundamentals and Practices, John Wiley & Sons, 2012.
7.	H. Weinstock, SQUID Sensors: Fundamentals, Fabrication and Applications, Springer Science & Business Media, 2012.
8.	Sam Zhang, Lin Li, Ashok Kumar, Materials Characterization Techniques, CRC Press, 2008.

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	**Course Title**	**L**	**T**	**P**	**C**
MNAT506P	**Nanomaterial Characterization Techniques Lab**	**0**	**0**	**2**	**1**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed to:

1. Make them understand various Nanostructure characterization techniques.
2. Train the students on state-of-the-art metrology tools such as Scanning Probe Microscopes and optical spectroscopes.
3. Enable them to study the morphologies and properties that are probed and measured.

Course Outcome

Students will be able to:

1. Prepare, characterize and analyze the samples with suitable techniques.

Indicative Experiments		
1.	Determine of size and lateral dimensions of various samples using optical microscope	4 hours
2.	Operation of Atomic Force Microscope (AFM).	4 hours
3.	Operation of Scanning Tunneling Microscope (STM).	4 hours
4.	Study of UV-Vis spectrophotometer and Determination of Concentration of unknown samples using Beer-Lambert's Law	4 hours
5.	Investigation of nanofluid inter- intra molecular interaction with ultrasonic wave using Nanofluid interferometer	4 hours
6.	Working operation of Electrochemical Workstation and testing of an electrolytic capacitor	4 hours
7.	Operation of Raman Spectroscopy	3 hours
8.	Study of electrical conductivity of thin film using Hall Effect analysis.	3 hours
	Total Laboratory Hours	**30 hours**

Mode of Assessment: Continuous Assessment and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title		L	T	P	C
MNAT507L	**Nanoelectronics**		**3**	**0**	**0**	**3**
Pre-requisite	**MNAT503L**	**Syllabus version**				
		1.0				

Course Objectives

The course is aimed to:

1. Make them understand various advanced concepts in nanoelectronics.
2. Explore the fundamentals on QED, SED, Molecular electronics and spintronics.
3. Train the students on state-of-the-art computational tools for modelling and simulation ofnanoelectronics devices.

Course Outcome

Students will be able to:

1. Develop the concepts of nanoelectronics such as ballistic transport and quantum confinement.
2. Understand various nanostructures and its applications towards Quantum Electronic Devices.
3. Build the fundamentals of Molecular Electronics
4. Obtain the knowledge of Single Electron Devices and carbon based nanoelectronic devices.
5. Define the fundamentals of Spintronics.
6. Design and simulate various advanced nanoelectronic devices.

Module	Title	Hours
Module:1	**Introduction to Nanoelectronics**	**6 hours**

Limitations of the conventional MOSFETs at Nanoscales, MOSFET Scaling & implications, Constant voltage and constant field scaling, Moore's law, current trends and challenges in scaling, Implications of quantum confinement and tunneling on nanoscale devices.

Module	Title	Hours
Module:2	**Nanostructures and Quantum Electronic Devices**	**6 hours**

Low-dimensional structures- Quantum wells, Quantum wires and Quantum dots; Density of states in low-dimensional structures; Quantum heterostructure, High Electron Mobility Transistors, Resonant tunneling phenomena and its applications in diodes and transistors.

Module	Title	Hours
Module:3	**Molecular Electronics**	**5 hours**

Overview & Basics; Fabrication of molecular electronics-based transistor devices; Conduction mechanism in organic polymers; Self-Assembling Circuits, Molecular FETs, Organic-LED.

Module	Title	Hours
Module:4	**Single Electron Devices**	**4 hours**

Tunnel junctions, Principle of operation- Single-Electron Effect, Coulomb Blockade Phenomenon; Theoretical Quantum Dot Transistor - Energy of Quantum Dot system, Single-Electron Quantum-Dot Transistor.

Module	Title	Hours
Module:5	**Carbon Nanoelectronics and 2D Materials Electronics**	**6 hours**

Carbon nanotubes - SWCNTs and MWCNTs; 1D quantization in nanotubes- van Hove singularities; Fabrication of CNTs; CNT FETs- Device characteristics, CNT-TUBFET, CNT-SET; and NanoWire FETs; Electronic structure of graphene; Graphene FETs- GNRFETs. Transition-metal dichalcogenide (TMD) material devices.

Module	Title	Hours
Module:6	**Spintronics**	**6 hours**

Fundamentals of Spintronics; Giant Magnetoresistance and Tunneling Magnetoresistance, Magnetic Tunneling Junctions, Spin Transfer Torque and Magnetic memories.

Module	Title	Hours
Module:7	**Current Nanoelectronic Devices**	**10 hours**

Quantum Effects in MOSFETs, Strained Silicon Double-Gate MOSFET, Multi-gate MOSFETs, FINFET, SOI MOSFET Structures, Partially Depleted and Fully Depleted SOI-MOSFETs, Nanowire and Nanosheet GAA FETs, Non-volatile flash Memories, Charge trap memories, Ballistic Transport, Conductance Quantization, Quantum Point Contact Devices.

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Shunri Oda, David Ferry, Nanaoscale Silicon Devices, CRC Press, Taylor & Francis Group, 2015.
2.	George W Hanson Fundamentals of Nanoelectronics Pearson India,2009
Reference Books	
1.	Suprio Datta, Lessons from nanoelectronics, World Scientific publisher, 2015.
2.	Karl Goser, Peter Glosekotter, Jan Dienstuhl , Nanoelectronics and Nanosystems-From Transistors to Molecular and Quantum Devices, Springer-Verlag 2004.
3.	C.N.R. Rao and A. Govindaraj, Nanotubes and nanowires, RSC Publishing, 2005.
4.	Konstantin K. Likharev, Single Electron Devices and their Applications, IEEE proceedings, vol. 87, no. 4, April 1999.p 606- 632.
5.	Ziese and M. J. Thornton Spin Electronics, Springer-Verlag, 2001.
6.	Supriyo Datta, Quantum Transport-From Atom to Transistor, Cambridge University press, 2005.

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	**Course Title**	**L**	**T**	**P**	**C**
MNAT507P	**Nanoelectronics Lab**	**0**	**0**	**2**	**1**
Pre-requisite	**MNAT503L**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed to:

1. Make them understand various advanced concepts in nanoelectronics.
2. Train the students on state-of-the-art computational tools for modelling and simulation of nanoelectronics devices.

Course Outcome

Students will be able to:

1. Design and simulate various advanced nanoelectronic devices.

Indicative Experiments		
1.	Write a matlab script for solving time independent Schrodinger equation in one dimension and obtain energy levels of electron confined in 1 dimensional infinite potential well with length L= 5 nm. Plot energy eigenfunction and probability as a function of x for first, fifth and seventh quantum states.	2 hours
2	Write Matlab script for solving Self-consistent Schrodinger-Poisson solver for MOS capacitor (Si-SiO2) in 1D with p-substrate with doping 5 x 10^{16} cm^{-3}, for a surface potential $2\varphi_f$. Plot i) the Electron charge density calculated classically as well as quantum mechanically. ii) Electric field profile and the band diagram	4 hours
3.	Design and fabricate below 100 nm technology node MOSFET using various process steps and extract threshold voltage and on resistance from its I-V characteristics using process and device simulators. Interpret the results using relevant physical mechanisms.	4 hours
4.	Design a 2D MOSFET structure in SDE with source and drain region of 100nm square, and simulation grid size of 1*2 micro meter. Source, drain doping of 1e19 cm-3 and p-substrate doping of 5e16 cm-3. Obtain Id-Vd characteristics for this device and also plot doping profile with grid and simulated charge density for one set of biasing conditions.	4 hours
5.	Design a Resonant Tunnelling Diode (RTD) with symmetric double barriers of various widths using AlGaAs/GaAs heterojunction material combination. Plot its transmission and I-V characteristics. Interpret the results with relevant physical mechanisms.	6 hours
6.	Design a double gate less than 50nm short channel MOSFET using high-K dielectrics. Plot its I-V characteristics and analyze its transport parameters. Interpret the results using relevant physical mechanisms.	6 hours
7.	Design and Simulate a SONOS memory device Gate bottom oxide thickness=2 nm, Gate silicon nitride thickness=6nm, Gate top oxide thickness=5nm. Choose suitable voltage ranges to obtain the program, erase and retention characteristics.	4 hours
	Total Laboratory Hours	**30 hours**

Mode of Assessment: Continuous Assessment and Final Assessment Test			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	**Course Title**	**L**	**T**	**P**	**C**
MNAT601L	**MEMS to NEMS**	**3**	**0**	**0**	**3**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed to:

1. Make them to understand the technology of MEMS and NEMS.
2. Expose them about fabrication processes for development of MEMS/NEMS devices and systems.
3. Educate about the potential applications of NEMS.

Course Outcome

Students will be able to:

1. Develop the knowledge of mechanisms in MESM/NEMS
2. Understand various engineering mechanics of microsystems
3. Develop the concept in finite element analysis of microsystems
4. Establish the knowledge of MEMS fabrication
5. Develop knowledge of quantum effects in MEMS/NEMS
6. Apply the knowledge of system integration in MEMS/NEMS
7. Design and simulate micro / nanosensors and actuators.

Module:1	**Introduction**	**4 hours**
Overview of MEMS / NEMS and various devices, Scaling geometry, Rigid Body Dynamics, Forces, Electron transfer, Fluid mechanics and Heat transfer.		
Module:2	**Engineering mechanics for Microsystems design**	**6 hours**
Static Bending of Thin plates, Mechanical vibration, Resonant vibration, Design theory of Accelerometers, and Thermal analysis, Thermal effects on Mechanical strength of Materials, Creep formation.		
Module:3	**Finite Element Analysis**	**7 hours**
Concept of FEA, Comparison with other methods, Formulation from the governing Differential equations, Formulation based on stationary total potential, 1-D and 2-D Finite Element Analysis, Examples.		
Module:4	**Overview of Micro - Scale fabrication**	**5 hours**
Microsystem fabrication process-Lithography, Dry and wet etching, Thin film deposition- PVD,CVD,LIGA, Micromolding, Electro-deposition		
Module:5	**Quantum effects**	**8 hours**
Casimir Force and its influence in MEMS and NEMS, control of casimir force, Nanotribology- experimental techniques for studying anotribology, phonic friction, electronic friction, static friction, frictional anisotropy, stick-slip dynamics		
Module:6	**NEMS**	**9 hours**
Introduction to nanoscale engineering, theory and characteristics of NEMS**,** Design and simulation techniques of NEMS – molecular dynamics, Potential energy models, Integration algorithms Molecular and Nanostructure Dynamics, Molecular Wires and Molecular Circuits		
Module:7	**System Integration**	**4 hours**
System Integration and reliability		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Tai-ran Hsu, MEMS and Microsystems: Design, Manufacture, and Nanoscale

	Engineering, 2nd Edition, 2008, John Wiley & Sons, New Jersey, United States
2.	Sergey Edward Lyshevski, MEMS and NEMS: Systems, Devices, and Structures, 2002, CRC Press, Florida, USA.
Reference Books	
1.	P.Seshu, Text Book of Finite Element Analysis, PHI,2006
2.	Sergey Edward Lyshevski, Nano- and Micro-electromechanical Systems, CRC, Press, 2000
3.	Bharath Bhushan, Handbook of Micro/Nanotribology, CRC Press, 1999.
4.	Cornelius T. Leondes, MEMS/NEMS Handbook, Techniques and application, Springer, 2005.
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.	

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title		L	T	P	C
MNAT602L	Nanosensors		3	0	0	3
Pre-requisite	NIL	Syllabus version				
		1.0				

Course Objectives

The course is aimed to:

1. Offer an overview of basic nanosensor technology with examples drawn from existing products and literatures.
2. Enable them to identify suitable nanosensors and nanodevices for various potential applications.
3. Make them acquainted with various types of nanosensors and its potential applications

Course Outcome

Students will be able to:

1. Identify and understand various mico and nano-sensors and their working.
2. Summaries materials properties used for the fabrication of nanosensors.
3. Explain fundamentals of packaging and characterization of nanosensors
4. Develop the various types of mechanical, chemical and optical nano-sensing systems.
5. Apply various nanostructured materials for developing nanobiosensors.

Module:1	Micro and nano-sensors	3 hours

Sensing principles, sensor types and classification – Mechanical, acoustic, magnetic, thermal, chemical, radiation; microsensors; sensors based on surface - acoustic wave devices, biosensor, microfluids

Module:2	Materials for Nanosensors	8 hours

Shape and size Dependence of Properties at Nanoscale, Surface Energy of a Solid, Core/Shell- Structured Nanoparticles, Metallic Nanoparticles and Plasmons Optical Properties of Bulk Metals and Metallic Nanoparticles, Quantum Dots, Carbon Nanotubes.

Module:3	Packaging and characterization of sensors	4 hours

Design, fabrication and characterization, Method of packaging at dye level, zero level and first level.

Module:4	Mechanical Nanosensors	8 hours

Mass sensing- Nanogram Mass Sensing by Quartz Crystal Microbalance, MEMS/NEMS Resonators; Displacement sensor- Electron Tunneling Displacement Nanosensor, Coulomb Blockade Electrometer-Based Displacement Nanosensor, Nanometer-Scale Displacement Sensing by Single-Electron Transistor, Magnetomotive Displacement Nanosensor, Piezoresistive and Piezoelectric Displacement Nanosensors, Optical Displacement Nanosensor.

Module:5	Chemical Nanosensors	8 hours

Gas Sensors Based on Metallic Nanoparticles, Metal Oxides, Carbon Nanotube, Porous Silicon; Thin Organic Polymer Film–Based Gas Sensors; Electrospun Polymer Nanofibers as Humidity Sensors; Nanoelectronic Nose.

Module:6	Optical Nanosensors	6 hours

Noble-Metal Nanoparticles with LSPR and UV–Visible Spectroscopy, Nanosensors Based on Surface-Enhanced Raman Scattering, Colloidal SPR Colorimetric Gold Nanoparticle Spectrophotometric Sensor, Fiber-Optic Nanosensors.

Module:7	Nanobiosensors	6 hours

Nanoparticle-Based Electrochemical Biosensors, CNT-Based Electrochemical Biosensors, Functionalization of CNTs for Biosensor, Quantum Dot-Based Electrochemical Biosensors.

Module:8	Contemporary Issues	2 hours
	Total Lecture hours:	**45 hours**

Text Book(s)				
1.	J. Chattopadhyay, N. Srivastava, Application of Nanomaterials in Chemical Sensors and Biosensors, CRC press, 2021.			
2.	Vinod Kumar Khanna, Nanosensors: Physical, Chemical, and Biological, CRC press, 2012			
Reference Books				
1.	H Chaudhery, K Suresh, Handbook of Nanomaterials for Sensing Applications, Elsevier, 2021			
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.				
Recommended by Board of Studies	28-07-2022			
Approved by Academic Council	No. 67	Date	08-08-2022	

Course Code	Course Title	L	T	P	C
MNAT603L	**Nanophotonics**	**3**	**0**	**0**	**3**
Pre-requisite	**MNAT503L**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed to:

1. Expose them to the emerging area of nanophotonics and the phenomena involved in such devices.
2. Provide deep understandings of light – matter interaction at nanoscale.
3. Study different types of nanophotonic crystal based devices and systems.

Course Outcome

Students will be able to:

1. Understand the mathematical synthesis of Maxwell equations for Photonic systems.
2. Analyze the light-matter interaction
3. Compare similarity between electrons and Photons.
4. Understand the knowledge of 1-D, 2-D and 3-D Photonic Crystals.
5. Apply photonic crystals for different applications.
6. Understand the plasmonics-based photonic circuits.

Module	Title	Hours
Module:1	**Maxwell equations for Photonic systems**	**6 hours**
Permittivity, Susceptibility, Dielectric Constant, Basic Maxwell equations and their interpretations, Wave Equations for dielectric.		
Module:2	**Light-Matter Interaction**	**5 hours**
Absorption, Scattering, Interference, Diffraction, Complex refractive index and dielectric constant, Dispersion in Materials, Fresnel reflection equations.		
Module:3	**Photons and Electrons - Similarities and differences**	**6 hours**
Photons and Electrons - Similarities and differences, Confinement of Photons and Electrons, Co-operative effects for Photons and Electrons, Propagation through Classically Forbidden Zone- Tunneling, Concept of Near-Field phenomena in Photonic Crystals and Evanescent wave. Master Equations for photonics		
Module:4	**Photonic Crystals**	**8 hours**
1-D, 2-D and 3-D Photonic crystal, Theoretical and mathematical description of Photonic band gap, Pass-band, Stop-band, Defects, Fabrication of Photonic crystals.		
Module:5	**Applications of Photonic Crystals- Stop band**	**6 hours**
1D Bragg mirrors, Waveguides, Filters, Fibers- Photonic bandgap fibers, Index Guiding fibers and Bragg fibers, logic-gates		
Module:6	**Applications of Photonic Crystals- Pass band**	**6 hours**
Construction of Equal frequency Surface, Superprism, Superlens, and Supercollimation		
Module:7	**PlasmonicsCO6**	**6 hours**
Fundamentals, wave equations, surface plasmon-polaritons, Plasmonic based photonic circuits		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Arthur McGurn, Nanophotonics (Hb 2018) Springer, 1st Edition, 2018, ISBN: 9783319770710
2.	John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, Robert D. Meade, Photonic

	Crystals: Molding the Flow of Light, second Edition, Princeton University Press, 2008
Reference Books	
1.	Motoichi Ohtsu, Kiyoshi Kobayashi, Tadashi Kawazoe, Takashi Yatsui, Makoto Naruse, Principles of Nanophotonics, CRC Press, Taylor & Francis Group, 2008.
2.	Stefan A. Maier, Plasmonics: Fundamentals and Applications, Springer Science, 2007.
3.	J. R. Lakowicz, Principle of Fluorescence Spectroscopy, third Edition, Kluwer Academic Publisher, Newyork, 2007
4	Paras Prasad, Nanophotonics, Wiley-Interscience, 2004.
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.	

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MNAT604L	**Lithographic Techniques for Device Fabrication**	**3**	**0**	**0**	**3**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed to:

1. Make conversant with conventional aspects of lithography, techniques related and their resolution aspects.
2. Introduce various existing Lithography techniques.
3. Study the principles, process steps and system components of the various lithographic techniques.

Course Outcome

Students will be able to:

1. Develop in-depth knowledge of optical and electron beam lithography techniques.
2. Differentiate the conventional features and resolution of lithography techniques such as X-ray, Ion, SPM based and soft lithography.
3. Understand the importance of plasmonics in lithography

Module	Title	Hours
Module:1	**Optical Lithography**	**9 hours**
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.		
Module:2	**Electron Beam Lithography**	**8 hours**
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.		
Module:3	**X-ray Lithography**	**4 hours**
X-ray lithography system components, Resolution enhancement, X-ray mask construction, X-ray sources, x-ray resists.		
Module:4	**Ion Lithography**	**3 hours**
Ion lithography system components; Focused Ion Beam Lithography; Masked Ion Beam Lithography; Ion Projection Lithography.		
Module:5	**Scanning Probe Lithography**	**8 hours**
Scratching Lithography; Anodic Oxidation- Mechanism of Nano-oxidation; Dip-Pen Nanolithography - Mechanism, DPN Types: Parallel DPN, Polymer DPN, Application of DPN; Nano-shaving.		
Module:6	**Soft Lithography**	**5 hours**
Micro-contact printing, Solvent-Assisted Micromoulding, Micromoulding in capillaries, Patterning SAMs.		
Module:7	**Plasmonic Nanolithography**	**6 hours**
Principle of Plasmonic Lithography, Plasmonic Mask, Near-field Plasmonic Lithography, Plasmonic Contact Lithography, Plasmonic direct write lithography.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	M Feldman, Nanolithography: The Art of Fabricating Nanoelectronic and Nanophotonic

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

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	**Course Title**		**L**	**T**	**P**	**C**
MNAT605L	**Plasmonics**		**3**	**0**	**0**	**3**
Pre-requisite	**MNAT503L**	**Syllabus version**				
		1.0				

Course Objectives

The course is aimed to:

1. Give a clear idea of changes in optical properties of nanostructures.
2. Enable to understand the fundamentals about surface plasmon polariton and plasmonic waveguides.
3. Make acquainted with various types of Spectroscopy and sensing techniques based on plasmonics.

Course Outcome

Students will be able to:

1. Apply the knowledge of electromagnetics on metallic nanoparticles.
2. Understand the fundamentals of surface plasmon polariton, and LSPR.
3. Understand the excitation dynamics at nanoscale.
4. Understand nanocomposites and its application in the field of optoelectronics.
5. Analyze the nanostructured molecular architectures.
6. Apply the basics on Surface-Plasmon-Polariton-Based for sensing and spectroscopy.

Module:1	**Electromagnetics of Metallic Nano-particles**	**9 hours**
Metallic Nano-particles, Maxwell equation and Electromagnetic wave equation, dispersion of the free electron gas and volume plasmons, real metals and intraband transitions, Electromagentic field in metals, Local Field Enhancement, Sub-wavelength aperture plasmonics		
Module:2	**Plasmonic waveguides**	**7 hours**
Elements for surface plasmon polariton propagation, surface plasmon polariton band gap structures, metal nanowires for high confinement guiding and focusing, localized modes, metal nanoparticle waveguides		
Module:3	**Localized surface plasmons**	**6 hours**
Normal modes of sub-wavelength metal particles, Mie theory, Observations of particle plasmons, coupling between localized plasmons, void plasmons and metallic nanoshells		
Module:4	**Nanocontrol of Excitation Dynamics**	**5 hours**
Nanostructure and excited states. Rare earth doped nanostructures Up-converting nanophores. Photon avalanche. Quantum cutting. Site isolating nanoparticles, prism and grating coupling, near field excitation.		
Module:5	**Nanocomposites**	**6 hours**
Nanocomposites as photonic media. Nanocomposite waveguides. Random lasers. Local field enhancement. Multiphase nanocomposites. Nanocomposites for optoelectronics. Polymer dispersed liquid crystals. Nanocomposite metamaterials.		
Module:6	**Nanostructured Molecular Architectures**	**5 hours**
Noncovalent interactions. Nanostructured polymeric media. Molecular machines. Dendrimers. Supramolecular structures. Monolayer and multilayer molecular assemblies.		
Module:7	**Spectroscopy and Sensing**	**5 hours**
Single-Particle Spectroscopy, Surface-Plasmon-Polariton-Based Sensors, Metamaterials and Negative Index at Optical Frequencies, The Perfect Lens, Imaging and Lithography.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Stefan Alexender Maier, Plasmonics – Fundamental and Applications, Springer, 2007.
2.	Paras Prasad, Nanophotonics, Wiley-Interscience, 2004.
Reference Books	
1.	Mark L. Brongersma and Pieter G. Kik, Surface Plasmon Nanophotonics, Springer, 2007.
2.	Ralf B. Wehrspohn, Heinz-Siegfried Kitzerow, and Kurt Busch, Nanophotonic Materials: Photonic Crystals, Plasmonics, and Metamaterials, Wiley-VCH, 2008)
3.	Matthew Pelton, Garnett W. Bryant, Introduction to Metal–Nanoparticle Plasmonics, A Wiley–Science Wise Co–Publication, 2013

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	**Course Title**	**L**	**T**	**P**	**C**
MNAT606L	**Nanomagnetism- Fundamentals and Applications**	**3**	**0**	**0**	**3**
Pre-requisite	**MNAT503L**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed to:
1. Make them understand the fundamentals of nanomagnetism and their applications.
2. Study the magnetism at macro- and nanoscale and their potential effects.
3. Enable students to apply the concepts of magnetic nanomaterials in the field of energy storage, biomedicine and environmental applications.

Course Outcome

Students will be able to:
1. Explain the concepts of magnetism at macro and nanoscale.
2. Summarize the knowledge about magnetism of localized electrons on the atom.
3. Relate the fundamentals of ferromagnetism, antiferromagnetism and other magnetic order.
4. Classify and understand the concepts of micro- and nanoscale magnetism
5. Interpret the concepts of magnetism and apply to magnetic nanomaterials for magnetic recording, energy storage, biomedicine and environmental applications.

Module:1	**Magnetostatics**	**3 hours**

Introduction - History - Magnetism and hysteresis, Magnetic dipole moment, Magnetic fields, Maxwell's equations, Magnetostatic energy and forces.

Module:2	**Magnetism of electrons**	**8 hours**

Orbital and spin moments, Magnetic field effects – Zeeman effect, Theory of electronic magnetism, Magnetism of electrons in solids.

Module:3	**Magnetism of localized electrons on the atom**	**8 hours**

The hydrogenic atom and angular momentum, The many-electron atom, Paramagnetism, Ions in solids; crystal-field interactions.

Module:4	**Ferromagnetism and Exchange**	**8 hours**

Mean field theory, Exchange interactions, Band magnetism, Collective excitations, Anisotropy, Ferromagnetic phenomena.

Module:5	**Antiferromagnetism and other magnetic order**	**4 hours**

Molecular field theory of antiferromagnetism, Ferrimagnets, Frustration, Amorphous magnets, Spin glasses, Magnetic models.

Module:6	**Micromagnetism and Nanoscale magnetism**	**7 hours**

Micromagnetic energy, Domain theory, Reversal, Pinning and Nucleation, Characteristic length scales, Superparamagnetism, Thin films, Thin-film heterostructures, Wires and needles, Small particles, Bulk nanostructures, Novel methods for synthesis of magnetic nanoparticles, Magnetic interactions: a tool to modify the magnetic properties of materials based on nanoparticles.

Module:7	**Applications of nanomagnetism**	**5 hours**

Magnetic storage and recording, Magnetic resonance Imaging, Hyperthermia, Ferrofluid, Biosensors.

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	B. D. Cullity, C. D. Graham, Introduction to Magnetic Materials, John Wiley & Sons, Inc, 2009.

2.	R. C. O'Handley, Modern Magnetic Materials: Principles and Applications, John Wiley & Sons, Inc, 2000.			
Reference Books				
1.	J. M. D. Coey, Magnetism and Magnetic Materials, Pearson Education, 2010.			
2.	C Binns, Nanomagnetism: Fundamentals and Applications, Elsevier, 2014.			
3.	David Jiles, Introduction to Magnetism and Magnetic Materials, Chapman and Hall, 1991.			
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.				
Recommended by Board of Studies		28-07-2022		
Approved by Academic Council		No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MNAT607L	Energy Technologies	3	0	0	3
Pre-requisite	MNAT502L	Syllabus version			
		1.0			

Course Objectives

The course is aimed to:

1. To expose the students about various energy sources and the possibility of harvesting energy with nanomaterials

Course Outcome

Students will be able to:

1. Understand the various renewable energy sources.
2. Apply the knowledge on different energy harvesting methods.
3. Understand thermodynamics and kinetics of fuel cell process with nanomaterials.
4. Explain and choose suitable nanomaterials and nanostructures for photovoltaics.
5. Distinguish different types and performance of solar collectors.
6. Develop the knowledge of electrochemical energy storage systems.
7. Understand the process and design issues in magnetic energy storage systems.

Module	Title	Hours
Module:1	Renewable Energy Sources	4 hours

Basics and Types of Renewable energy sources.

Module	Title	Hours
Module:2	Energy Harvesting	5 hours

Sources, Types and mechanism – Solar, Thermoelectric, Piezoelectric; Electro dynamical and Biological; Energy harvesting devices and applications. Nanomaterials for energy harvesting.

Module	Title	Hours
Module:3	Energy Conversion I	7 hours

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.

Module	Title	Hours
Module:4	Energy Conversion II	7 hours

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.

Module	Title	Hours
Module:5	Energy Conversion III	7 hours

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.

Module	Title	Hours
Module:6	Energy storage I	7 hours

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.

Module	Title	Hours
Module:7	Energy storage II	6 hours

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.

Module	Title	Hours
Module:8	Contemporary Issues	2 hours

	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Chetan Singh Solanki, Solar Photovoltatics – Fundamentals, Technologies and Applications, 2015, PHI Learning Private limited.
2.	Ru-Shi Liu, Jiujun Zhang, Hansan Liu, Andy Sun, Zhang Lei, Electrochemical technologies for energy storage and conversion, 2012, Wiley publications.

Reference Books

1.	Caye M. Drapcho, Nghiem Phu Nhuan and Terry H. Walker, Biofuels Engineering, McGraw- Hill Companies, 2008
2.	Viswanathan, B and M Aulice Scibioh, Fuel Cells – Principles and Applications, Universities Press ,2006
3.	Schaeffer, John, Real Goods Solar Living Sourcebook: The Complete Guide to Renewable Energy Technologies and Sustainable Living, Gaiam,2007
4.	Frank Kreith and D.Yogi Goswami, Handbook of Energy Efficiency and Renewable Energy, CRC Press, 2007
5.	John Twidell and Tony Weir, Renewable Energy Resources, Taylor & Francis, USA, 2006

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MNAT608L	**Spintronics**	**3**	**0**	**0**	**3**
Pre-requisite	**MNAT503L**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed to:
1. To make the students understand the spin based electronics.
2. To study the magnetic materials, Spintronic based devices and fabrication

Course Outcome

Students will be able to:
1. Classify the different magnetic materials.
2. Develop the knowledge of micromagnetic concepts
3. Apply the phenomena of transport in magnetic systems
4. Analyze the magnetic characterization tools
5. Apply Spintronics concepts to design futuristic products.

Module	Title	Hours
Module:1	**Paramagnetism& diamagnetism**	**6 hours**
Magnetically ordered state, Itinerant-electron magnetism, Localized Magnetic Systems.		
Module:2	**Micromagnetics**	**6 hours**
Magnetism of single domain systems, Domain Walls, Exchange Bias and Magnetic Anisotropy.		
Module:3	**Magnetic Materials**	**6 hours**
High-density recording materials, Soft Magnetic Materials (Ferrites), Magnetic Thin Films, Dilute Magnetic semiconductors, Hemsler Alloys, SQUID Magnetometer, Highly Spin Polarized Systems, Molecule-based magnets, Single-molecule magnets.		
Module:4	**Electron Transport in Magnetic Systems**	**6 hours**
Degree of Spin Polarization, Idea of Tunneling, Magnetoresistance, Anisotropic Magnetoresistance (AMR), Hall Effect (Planar & Anomalous) and Spin Polarized states.		
Module:5	**Characterization of Magnetic Materials**	**6 hours**
Magnetometry, SQUID, VSM, Torque, Faraday Balance, Kerr Effect, Magnetic Force Microscopy, Spin Polarized STM.		
Module:6	**Spintronic Devices**	**8 hours**
Spintronics- Origins of Spin, Spin Mechanics, Origins of Spintronics, Spin current and Magnetoresistance, Giant Magnetoresistance (GMR), Colossal Magnetoresistance, Ballistic Magnetoresistance, Tunneling Magnetoresistance. Two-terminal devices-Spin valves, Tunneling MR devices, Magnetic Field sensors, Read- Heads, MRAMS, Three-terminal Devices- Spin FET, Spin SET, and Spin LED.		
Module:7	**Spintronic Device fabrication Techniques**	**5 hours**
Advanced device fabrication methods-Growth of multilayer Structures, Lithography and Self-Assembly.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Hirota, Sakakima, and Inomata, "Giant Magneto-Resistive Devices", Springer Verlag 2002.
2. D. Awschalom, D. Loss, and N.Samarth, "Semiconductor Spintronics and Quantum Computation", Nano Science Technology series, Springer, 2002.

Reference Books			
1.	Stefan Visnovsky, “Optics in Magnetic Multi-layers and Nanostructures”, CRC Publishers, 2006.		
2.	D.L. Mills, J. A.C. Brand “Nanomagnetism”, Elsevier Science and Technology, 2006.		
3.	M. Ziese, M. J. Thornton “Spin Electronics”, Lecture Notes in Physics, Springer, 2001.		
4.	Gersten and Smith, “The Physics and Chemistry of Materials”, Wiley, 2001.		
5.	Buschow and De Boer, “Physics of Magnetism and Magnetic Materials”, Springer 2003.		
6.	R. L. Carlin, “Magnetochemistry”, Springer-Verlag, Berlin, 1986.		
7.	U. N.Hartmann, “Magnetic Multi-layers and Giant Magnetoresistance: Fundamentals and Industrial Applications”, Springer, 2000.		
8.	M. Ziese, M. J. Thornton “Spin Electronics”, Lecture Notes in Physics, Springer, 2001.		
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.			
Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MNAT609L	Nanoelectronic Circuit Design	3	0	0	3
Pre-requisite	MNAT507L	Syllabus version			
		1.0			

Course Objectives

The course is aimed to:
1. To introduce students to the emerging design paradigms in various new nanotechnologies, for device and circuits.
2. To bridge the existing gap between nanoelectronic device research and nanosystems design.

Course Outcome

Students will be able to:
1. Obtain the knowledge on advanced Nanoscale devices
2. Understand the operation and design FinFET based circuits.
3. Design reliable circuits using nanowire arrays and CNT interconnects.
4. Design logic circuits using quantum cellular automata.
5. Understand the design aspects of application specific Nanoscale ICs.
6. Model the circuits of Fin-FETs, CNT-FETs, GNR-FETs, RTDs and quantum dot devices using various SPICE versions.

Module:1	Introduction to advanced nanoelectronic devices	2 hours

New device structures for next generation nanotechnology - carbon nanotube field-effect transistors (CNFETs), FinFETs, nanowire FETs, III/V compound-based devices, graphene nanoribbon devices, resonant tunneling diodes and quantum dot devices.

Module:2	FinFET circuit and SRAM design	8 hours

Shorted-Gate and Independent-Gate FinFETs, Logic Design Using SG/IG-Mode FinFETs, Principle of TCMS, Logic Design Using TCMS, Latch Design Using SG/IG-Mode FinFETs, Precharge-Evaluate Logic Circuits, FinFET SRAM Design: Physics, Theory, and Modeling of FinFET Devices for SRAM Applications; Low-Power, High-Performance 90-nm DG-FinFET SRAM Design.

Module:3	Reliable Circuits Design with Nanowire Arrays and CNT Interconnects	7 hours

Nanowire Fabrication Techniques, Crossbar Technologies, Architecture of Nanowire Crossbars, Decoder Logic Design. Emerging interconnect technologies: Study of Performances of Low-k Cu, CNTs, and Optical Interconnects; Local Interconnects: CNT Bundles Versus Cu and Global and Semi-global Interconnects.

Module:4	Circuit Design with Quantum Cellular Automata	7 hours

QCA Fundamentals, Basic Logic Gates and Interconnect, Logic Design with QCA and Fabrication Technology and Challenges.

Module:5	Nanoscale Application-Specific Integrated Circuits	6 hours

NASIC Building Blocks: Nanowires and xnwFETs, NASIC Circuit Styles, NASIC Logic Styles, NASIC Architectures and manufacturing methods.

Module:6	Circuit Design with Carbon Nanotube FETs & Resonant Tunneling Diodes	8 hours

Mis-Positioned and Immune CNT Logic Design, Metallic-CNT-Immune CNFET Circuits. Metallic-CNT-Immune CNFET Circuits. Bistable Logic Using RTDs, Noise Margins of RTD–HBT Threshold Logic Gates, Monostable–Bistable Logic Elements and Circuit Examples for RTD-Based Devices.

Module:7	Circuit design with Graphene based Transistors	5 hours

Recent developments in Graphene Transistors, Analog Circuits, Digital Circuits: GNRFET

Digital Circuits, Ambipolar Logic Circuits.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**
Text Book(s)		
1.	K. Goser, P. Glosekotter, Nanoelectronics and Nanosystems, 2015, Springer Publications.	
2.	Niraj K. Jha and Deming Chen, Nanoelectronic Circuit Design, 2011, Springer publications.	
Reference Books		
1.	Yuan Taur and TakNing, Fundamentals of Modern VLSI Devices, Cambridge University Press, Newyark, 1998.	
2.	Karl Goser, Peter Glosekotter, Jan Dienstuhl, Nanoelectronics and Nanosystems-From Transistors to Molecular and Quantum Devices, Springer-Verlag, 2004.	
3.	John P. Uyemura, Introduction to VLSI Circuits and Systems, John Wiley & Sons, Inc, 2002.	
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test.		

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MNAT696J	**Study Oriented Project**				**02**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

1. The student will be able to analyse and interpret published literature for information pertaining to niche areas.
2. Scrutinize technical literature and arrive at conclusions.
3. Use insight and creativity for a better understanding of the domain of interest.

Course Outcome:

1. Retrieve, analyse, and interpret published literature/books providing information related to niche areas/focused domains.
2. Examine technical literature, resolve ambiguity, and develop conclusions.
3. Synthesize knowledge and use insight and creativity to better understand the domain of interest.
4. Publish the findings in the peer reviewed journals / National / International Conferences.

Module Content	**(Project duration: One semester)**

This is oriented towards reading published literature or books related to niche areas or focussed domains under the guidance of a faculty.

Mode of Evaluation: Evaluation involves periodic reviews by the faculty with whom the student has registered. Assessment on the project – Report to be submitted, presentation and project reviews – Presentation in the National / International Conference on Science, Engineering Technology.

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	**Course Title**	**L**	**T**	**P**	**C**
MNAT697J	**Design Project**				**02**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

1. Students will be able to design a prototype or process or experiments.
2. Describe and demonstrate the techniques and skills necessary for the project.
3. Acquire knowledge and better understanding of design systems.

Course Outcome:

1. Develop new skills and demonstrate the ability to upgrade a prototype to a design prototype or working model or process or experiments.
2. Utilize the techniques, skills, and modern tools necessary for the project.
3. Synthesize knowledge and use insight and creativity to better understand and improve design systems.
4. Publish the findings in the peer reviewed journals / National / International Conferences.

Module Content	**(Project duration: One semester)**

Students are expected to develop new skills and demonstrate the ability to develop prototypes to design prototype or working models related to an engineering product or a process.

Mode of Evaluation: Evaluation involves periodic reviews by the faculty with whom the student has registered. Assessment on the project – Report to be submitted, presentation and project reviews – Presentation in the National / International Conference on Science, Engineering Technology.

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	**Course Title**	**L**	**T**	**P**	**C**
MNAT698J	**Internship I/ Dissertation I**				**10**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

To provide sufficient hands-on learning experience related to the design, development and analysis of suitable product / process so as to enhance the technical skill sets in the chosen field and also to give research orientation.

Course Outcome:

1. Considerably more in-depth knowledge of the major subject/field of study, including deeper insight into current research and development work.
2. The capability to use a holistic view to critically, independently and creatively identify, formulate and deal with complex issues.
3. A consciousness of the ethical aspects of research and development work.
4. Publications in the peer reviewed journals / International Conferences will be an added advantage.

Module Content **(Project duration: one semester)**

1. Dissertation may be a theoretical analysis, modeling & simulation, experimentation & analysis, prototype design, fabrication of new equipment, correlation and analysis of data, software development, applied research and any other related activities.
2. Dissertation should be individual work.
3. Carried out inside or outside the university, in any relevant industry or research institution.
4. Publications in the peer reviewed journals / International Conferences will be an added advantage.

Mode of Evaluation: Assessment on the project - Dissertation report to be submitted, presentation, project reviews and Final Oral Viva Examination.

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MNAT699J	**Internship II/ Dissertation II**				**12**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			
Course Objectives:					
To provide sufficient hands-on learning experience related to the design, development and analysis of suitable product / process so as to enhance the technical skill sets in the chosen field.					
Course Outcome:					
Upon successful completion of this course students will be able to 1. Formulate specific problem statements for ill-defined real life problems with reasonable assumptions and constraints. 2. Perform literature search and / or patent search in the area of interest. 3. Conduct experiments / Design and Analysis / solution iterations and document the results. 4. Perform error analysis / benchmarking / costing. 5. Synthesize the results and arrive at scientific conclusions / products / solution. 6. Document the results in the form of technical report / presentation.					
Module Content	**(Project duration: one semester)**				
1. Dissertation may be a theoretical analysis, modeling & simulation, experimentation & analysis, prototype design, fabrication of new equipment, correlation and analysis of data, software development, applied research and any other related activities. 2. Dissertation should be individual work. 3. Carried out inside or outside the university, in any relevant industry or research institution. 4. Publications in the peer reviewed journals / International Conferences will be an added advantage.					
Mode of Evaluation: Assessment on the project - Dissertation report to be submitted, presentation, project reviews and Final Oral Viva Examination.					

Recommended by Board of Studies	28-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022