M. Tech. in Nano Technology

Scheme of Study (July 2021)

First Semester:

Course No.	Subject	Scheme of studies periods per week			Total Credits
		L	T	P	
NT 511	Computational Methods	3	-	-	3
NT 512	Structure and Properties of Solids	3	-	-	3
NT 513	Properties of Nano Materials	3	-	-	3
NT 514	Processing and Fabrication of Nanostructures	3	-	-	3
HUM 511	Communication Skills	2	-	-	2
	Elective-1 (A)	3	-	-	3
	Elective-2 (A)	3	-	-	3
NT 515	Nanotechnology Lab 1	-	-	2	1
NT 516	Seminar-1	-	-	2	1
Total Hours: 24 **Total Credits: 24**		**Total Semester Credits**			**22**

Second Semester:

Course No.	Subject	Scheme of studies periods per week			Total Credits
		L	T	P	
NT 521	Nanostructure Characterization Techniques	3	-	-	3
NT 522	Properties of Low-dimensional System	3	-	-	3
NT 523	Instrumentation	3	-	-	3
	Elective-3 (A)	3	-	-	3
	Elective-4 (A)	3	-	-	3
	Elective-5 (C)	3	-	-	3
NT 524	Research Methodology	1	1	-	2
NT 525	Nanotechnology Lab 2	-		2	1
NT 526	Seminar-2	-	-	2	1
Total Hours: 24 **Total Credits: 44**		**Total Semester Credits**			**22**

Third Semester:

Course No.	Subjects	Scheme of studies period per week			Total Credits
		L	T	P	
NT 611	Dissertation Phase-I	-	-	32	16
Total Hours: 32 **Total Credits: 60**		**Total Semester Credits**			**16**

Fourth Semester:

Course No.	Subjects	Scheme of studies period per week			Total Credits
		L	T	P	
NT 621	Dissertation Phase-II	-	-	40	20
Total Hours: 40 **Total Credits: 80**		**Total Semester Credits**			**20**

Grand Total of Course Credits = 24 + 24 + 16 + 20 = 80

List of Electives A		List of Electives C	
NT551	Nano Fluids & Surfaces	ARP - 581	Introduction to Urban Planning
NT552	Optoelectronics	BSE – 581	Bioprocess Engineering
NT553	Photonic Materials	BSE – 582	Biophysics Tools and Techniques
NT554	Nonlinear Dynamics	CHE – 581	Analytical Techniques
NT555	General Theory of Relativity	CHE – 582	Green Technology & Processes
NT556	Quantum Computing	CE – 582	Basic Concept of GIS
NT557	Semiconductor devices	CE – 583	Road Safety
NT558	Amorphous Materials	CSE – 581	Machine Learning
NT559	Low Temperature Behavior of Materials	CSE – 582	Advanced Data Structures and Algorithms
NT560	Molecular Electronics and Biomolecules	PHY – 581	Nanotechnology and Nanoscience
NT561	Quantum Optics	EE – 581	Electric Machines & Applications
NT562	Methods in Experimental Nuclear and Particle Physics	EE – 582	Control and Instrumentation
NT563	Renewable Energy Technologies	EC - 581	Energy Resource Technologies
NT564	Soft Matter Physics	HUM – 581	Intellectual Property Rights for Engineers
NT565	Computational Physics	HUM – 582	Applied Psychology: Human Centered Design and Engineering
NT566	Laser Technology	MTH – 581	Advanced Operations Research
NT567	Nano Electronics	MTH – 582	Computing Technologies
NT568	Solar Photovoltaic Technology	ME – 581	Value Engineering
NT569	Optical Sensors	ME – 582	Design Thinking
NT570	Advanced Electromagnetic Theory	ME - 583	Mechatronics and NDT in Engineering
NT571	Molecular Structures	MME – 581	Advanced Instrumentation Methods for Material Analysis
NT572	Advanced Magnetic Materials and their Applications	MME – 582	Smart Materials and their Application
NT573	Advanced Topics in Physics	MBA-581	Engineering Startup Management
NT574	Physics of Quantum Devices		
NT575	Quantum Field Theory		

- **Group A: Program Electives.**
- **Group B: Departmental Electives** (Not offered as there is no other M.Tech. Program in the Physics Deaprtment)
- **Group C: Open Electives.**

Syllabus

Name of Program	**M.Tech. (Nanotechnology)**	**Semester: 1st**	**Year: 2021-22**

Name of Course	**Computational Methods**
Course Code	**NT-511**
Core / Elective / Other	**Core**

Prerequisite:

1.	Basic integration and differentiation, Matrix, Quantum mechanics

Course Outcomes: At the end of the course, the student will be able to:

1.	Describe special functions and their recurrence relations
2.	Calculate eigenvalues and eigenvectors of a matrix
3.	Apply different C++ language and simulations to solve Engineering problem.

Description of Contents in brief:

1.	Differential equation
2.	Special functions Bessel's, Hermite's. Laguerre polynomials
3.	Eigen value, Eigen functions
4.	Perturbation theory
5.	Numerical analysis
6.	Idea of visual basic, C++ and c-sharp

List of Text Books:

1.	Mathematical Methods for Physicists: George Arfken, Hans Weber and Harris, (Academic Press)
2.	Numerical Computational Methods, P. B. Patil and U. P. Verma, (Alpha Science International)
3.	Introductory Methods of Numerical Analysis: S.S. Sastry (PHI)
4.	Numerical Methods in Engineering and Science: B.S. Grewal and J.S. Grewal (Khanna Publishers)
5.	Mathematics for Physics:Adam Marsh, (World Scientific Publishing Company)

List of Reference Books:

1.	Mathematical Physics, H.K. Dass, Rama Verma, (S.Chand)
2.	Matehmatical Physics, S.S. Rajput, (Pragati Publication)
3.	Mastering Visual Basic 6: EvangelosPetroutsos, (BPB Publications)
4.	Visual Basic & C++, Shyaum Series
5.	The C++ Programming Language: Bjarne Stroustrup, (Addison-Wesley)
6.	Numerical Methods: Timothy Sauer (Pearson)
7.	Numerical Methods for Scientists and Engineers: Richard Hamming (Dover Publications)
8.	Algebra 1 Workbook: Richard Carter (Independently published)
9.	Visual Basic:Mike McGrath (In Easy Steps Publishers Limited)

URLs:	
1.	https://nptel.ac.in/courses/115/106/115106118/
2.	https://nptel.ac.in/courses/115/104/115104095/
3.	https://swayam.gov.in/nd1_noc19_ph16/preview
4.	https://nptel.ac.in/courses/106/105/106105151/
5.	https://nptel.ac.in/courses/111/106/111106101/
6.	https://nptel.ac.in/courses/106/101/106101208/
7.	https://nptel.ac.in/courses/111/106/111106100/
8.	https://nptel.ac.in/courses/115/106/115106066/

Lecture Plan (about 40-50 Lectures):

Lecture No.	**Topic**
Lecture 1	Introduction: Computational Methods, Application
Lecture 2	Differential Equation: First-order equations
Lecture 3	Ordinary differential equation with constant coefficient
Lecture 4	Second-order linear Ordinary differential equations
Lecture 5	Inhomogeneous linear Ordinary differential equations
Lecture 6	Partial differential equations: Introduction, application
Lecture 7	Laplace equation
Lecture 8	Tutorial on differential equation
Lecture 9	Special Function, Bessel functions of the first kind
Lecture 10	Orthogonality
Lecture 11	Neumann functions
Lecture 12	Bessel function of second kind
Lecture 13	Hermite functions
Lecture 14	Laguerre functions
Lecture 15	Tutorial on special functions
Lecture 16	Eigenvalue Equations
Lecture 17	Matrix eigenvalue problems
Lecture 18	Hermitian eigenvalue problems
Lecture 19	Hermitian matrix diagonalization
Lecture 20	Tutorial on eigenvalue equations
Lecture 21	Eigen vectors
Lecture 22	Properties of eigen vectors, orthogonal vectors
Lecture 23	Tutorials on eigenvectors
Lecture 24	Perturbation Theory: Time-dependent perturbation theory
Lecture 25	Transition probability
Lecture 26	Constant perturbation
Lecture 27	Harmonic perturbation
Lecture 28	Tutorial on perturbation theory
Lecture 29	Numerical Analysis: Integration, Trapezoidal Rule
Lecture 30	Measuring Errors, Sources of Error, Propagation of Errors
Lecture 31	Finite Difference Methods
Lecture 32	Taylor Series
Lecture 33	Continuous Functions, Discrete Functions
Lecture 34	Interpolation Background, Newton's Divided Difference Method
Lecture 35	Linear Regression, Nonlinear Regression, Direct method
Lecture 36	Lagrange Method

Lecture 37	Python Fundamentals
Lecture 38	Differentiation
Lecture 39	Tutorial on numerical integration and differentiation
Lecture 40	System of linear & non-linear equation: Euler method, Iteration method,
Lecture 41	Bisection Method, Runge-Kutta Method
Lecture 42	Newton-Raphson Method
Lecture 43	Tutorial on numerical analysis
Lecture 44	Introduction: C++, Visual basic
Lecture 45	C++ Programming basics
Lecture 46	Functions
Lecture 47	Object and Classes
Lecture 48	Arrays and string arrays
Lecture 49	Programming with c-sharp, Arrays and strings, Sorting and searching

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 1st**	**Year: 2021-22**
Name of Course	**Structure and Properties of Solids**		
Course Code	**NT-512**		
Core / Elective / Other	**Core**		

Prerequisite:

1.	Atoms, Basic types of interatomic bonds: covalent, ionic, metallic bonding, Vander Waals interactions, dipolar interactions, hydrogen bonding.

Course Outcomes:

1.	To strengthen the basic concepts of crystalline materials in general. Detailed study of types of materials, bonding, and defects. Processing of Electrocramics
2.	To establish theoretical background about different hypothesis which explain the electrical, magnetic and thermal mechanism in various types of materials.
3.	Detailed study of Transport, dielectric and magnetic properties of materials.
4.	Classification of solids based on structure, and properties like crystalline non crystalline, magnetic, ceramics, polymers and composites

Description of Contents in brief:

1.	Crystal Bonding and Structure: Crystalline, polycrystalline and Non-crystalline solid, Defects in solids. Interaction of X-ray with matter, Bragg's law, X-ray diffraction Techniques: Powder & Single Crystal diffraction, Synchrotron XRD. Scattering theory-elastic and inelastic scattering (Raman and Rayleigh), Free electron theory, Band theory of solids. Transport properties: electrical, thermal, dielectric and magnetic. Electro ceramics preparation, calcinations, shaping and processing, dielectric, magnetic ceramics, ferrites. Polymers: types, structures, characteristics, application and processing of polymers. Composites: particle reinforced, fiber reinforced, structural composites.

List of Text Books:

1.	Solid State Physics, S. O. Pillai (New Age International Publisher, New Delhi)
2.	Solid State Physics, M. A. Wahab (Narosa Publishing House, New Delhi)
3.	Theoretical Solid-State Physics: William Jones, Norman H. March (Dover Publications)
4.	Materials Science and Engineering: V. Ragahvan (Prentice Hall)

List of Reference Books:

1.	Introduction to Solid State Physics; C. Kittel (John Wiley & Sons, USA)
2.	Materials Science and Engineering, W.D. Callister (John Wiley & Sons, USA)
3.	Elements of X-ray diffraction, B. D. Culity (Pearson, UK)
4.	Introduction to Magnetic Materials, B. D. Culity (Wiley, USA)
5.	Nanocomposite Science and Technology, Ajayan, Schalder&Barun(John Wiley & Sons)
6.	Materials Science and Technology: Sabar D. Hutagalung (Intech Publishers)
7.	Physics of Materials: Dr. PrathapHaridoss (Wiley VCH)
8.	Understanding Solid State Physics**:** Sharon Ann Holgate (CRC Press)
9.	The Science and Design of Engineering Material: James P. Schaffer, Ashok Saxena, Stephen D. Antolovich, Thomas H. Sanders Jr., Steven B. Warner (McGraw Hill)
10.	Electroceramics: Materials, Properties, Applications: A. J. Moulson J. M. Herbert (John Wiley & Sons, Ltd)
11.	An Introduction to Synchrotron Radiation: Techniques and Applications:Philip Willmott (John Wiley & Sons)

URLs:	
1.	https://www.sciencedirect.com/topics/materials-science/structural-polymer
2.	https://application.wiley-vch.de/books/sample/3527412824_c01.pdf
3.	https://nptel.ac.in/courses/115105099/
4.	https://nptel.ac.in/courses/115104109/
5.	https://nptel.ac.in/courses/115106061/
6.	https://www.iucr.org/education
7.	https://podcasts.ox.ac.uk/series/oxford-solid-state-basics
8.	https://ocw.mit.edu/courses/physics/
9.	https://jp-minerals.org/vesta/en/download.html
10.	http://physics-ref.blogspot.com/2012/12/clausius-mossotti-equation-static.html
11.	https://www.nrel.gov/docs/fy00osti/22211.pdf
12.	https://cds.cern.ch/record/817295/files/0471680575_TOC.pdf
13.	https://nptel.ac.in/courses/113105015/
14.	http://www.issp.ac.ru/ebooks/books/open/Materials_Science_and_Technology.pdf
15.	https://www.embl-hamburg.de/biosaxs/courses/embo2012/slides/x-ray-scattering-basics-roessle.pdf

Lecture Plan (about 40-50 Lectures):

Lecture No.	**Topic**
1.	Bonding in solids, their types (Ionic, Covalent, Metallic and Hydrogen) and their properties with suitable examples
2.	Introduction to crystal structures of solid, Bravais lattice and some basic terms and definitions in crystal structure
3.	Determination of co-ordination number and packing factor. Symmetry in crystals and some cubic structures e.g. NaCl, CsCl, ZnS etc.
4.	Evaluation of Miller indices and related numerical problems
5.	Derivation of expression of Inter planar spacing for various crystals
6.	Types of materials: crystalline, polycrystalline and amorphous. Imperfection in crystals and its cause (e.g. thermal vibration)
7.	Defects in Crystals: Point Defect, Schottky and Frenkel defects
8.	Derivation for Equilibrium concentration of vacancies in different types of defects
9.	Defects in solid: Line defect (Edge and Screw dislocation), Burger vector
10.	Volume Defect, Surface defect: grain, tilt and twin boundaries, Numerical
11.	Interaction of X-ray with Matter and its application for material characterization
12.	X-ray diffraction: origin and characteristic X-rays. Derivation of Braggs law of XRD
13.	X-ray diffraction techniques to determine the crystal structure. Laue's and Rotating crystal method for XRD
14.	Powder method of X-ray diffraction and reciprocal lattice, Numerical problems
15.	Basics of Synchrotron radiation and its application for material characterization, advantage of synchrotron radiations
16.	Scattering theory-elastic and inelastic scattering:Raman and Rayleigh scattering
17.	Introduction to free electron gas theory of solid and some results of classical assumptions

18.	Drawback of classical free electron theory and concept of Somerfield's quantum free electron theory of solids
19.	Quantum free electron theory; behavior of electron in constant potential
20.	Application of free electron theory of solid and transport properties
21.	Drawback of free electron theory of solid and introduction to Band theory of solid
22.	Band Theory of solid: behavior of electron in periodic potential
23.	Kronig-Penney model
24.	Energy vs Wave vector diagram (E-k diagram)
25.	Classification of metal, insulator and semiconductor on the basis of band theory of solids
26.	Electrical properties: Energy bands of solids and classification of solids, Concepts of holes, effective mass, Drift, mobility and conductivity
27.	Intrinsic semiconductors and extrinsic semiconductors, Fermi-Dirac distribution function and Fermi energy level in a conductor, insulator
28.	Thermal properties: Specific Heat, thermal conductivity, Thermal expansion and thermal stresses
29.	Dielectric properties: Dielectric materials, Dielectric polarization- electronic, ionic and orientational
30.	Complex permittivity, frequency response of dielectric materials, dielectric loss
31.	Relation between dielectric constant with microscopic polarizability: Clausius- Mossotti equation
32.	Magnetic properties: Magnetic materials, types of magnetic material (Diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic, and ferrimagnetic
33.	Magnetic Domains and Hysteresis loop, effect of temperature on magnetic properties of materials
34.	Hard and soft magnetic materials, magnetic anisotropy, Magnetic properties of nanomaterials
35.	Ferrites: types, properties and applications
36.	Electro ceramics-preparation, calcinations, shaping and processing
37.	Dielectric and magnetic ceramics
38.	Polymer: Basics, weight, structure, shape, types, defects and applications
39.	Copolymer, Thermoplastic and thermosetting polymer, mechanical and thermal behavior of polymers, conducting polymers
40.	Synthesis and processing of polymers
41.	Composite materials, Particle-reinforced composite, Fiber reinforced composite
42.	Structural composites, Nanocomposites- properties and applications

Name of Program	M. Tech. (Nanotechnology)	Semester: 1st	Year: 2021-22

Name of Course	**Properties of Nano Materials**
Course Code	**NT-513**
Core / Elective / Other	**Core**

Prerequisite:	
1.	Basics of quantum mechanics
2.	Band gap in solids
Course Outcomes: At the end of the course, the student will be able to	
1.	Understand the theoretical concepts of nanotechnology with the help of different models.
2.	Conceptualize quantum confinement, types of nanomaterials – 1D,2D,3D nanomaterials
3.	Understand and use the most important nanomaterial C60 and Fullerene with their special structure and bonding which makes them special
4.	Understand Different properties like transport thermal and mechanical properties of carbon nano tubes for recent application
5.	Capable to synthesis and characterize nano materials with controlled structure and tuned band gap
6.	Synthesis nanomaterials and combine it with advanced technology like NEMS and MEMS.
Description of Contents in brief:	
1.	Introduction to Nanotechnology: Characteristic scale for quantum phenomena-Quantum Confinement. Drexler-Smalley debate and historical and environmental evidences. Electronic structures-Quantum well, quantum dots, quantum wires. Nano-clusters. Structure and bonding. The Jellium Model. Discovery of C_{60}.Fullerene. Carbon Nano Tubes-types, structures, synthesis of CNTs. Transport, Optical, Thermal and Mechanical Properties of Nano tubes. Application of Nano Materials. Micro & Nano Electromechanical Systems.
List of Text Books:	
1.	D.Bimberg, M.Grundman, N.N. Ledenstov: Quantum Dot Heterostructure (World Scientific Singapore)
2.	Dresselhaus M.S. &Avouris: CNT Synthesis, Structure (Springer)
3.	Nanoscience and Nanotechnology:Shubra Singh M.S. Ramachandra Rao (Wiley –VCH)
List of Reference Books:	
1.	Advances in Nanomaterials:Balasubramanian, Ganesh (Springer)
2.	Nanoscience and Nanotechnology: Advances and Developments in Nano-sized Materials:Marcel Van de Voorde (De Gruyter Publishers)
URLs:	
1.	http://www.physics.dcu.ie/~jpm/PS407/dot.pdf
2.	https://www.nanotech-now.com/
3.	https://nptel.ac.in/courses/113/106/113106040/
4.	http://stanford.edu/~oas/SI/QM/papers/QMGreensite.pdf
Lecture Plan (about 40-50 Lectures):	

Lecture No.	Topic
1.	Recall bonding and band gap in solids
2.	Introduction to Nanotechnology and length scale
3.	Nanotechnology in Nature
4.	Historical evidence Nanotechnology
5.	Properties of solids depending on band gap
6.	Characteristic scale of quantum phenomena
7.	Quantum confinement
8.	0D, 1D, 2D and 3d structure of materials
9.	Energy state and bandgap in 0D, 1D, 2D and 3d structure
10.	Effect of confinement on properties of materials
11.	Quantum well, quantum dots, quantum wires
12.	Bnadgap tuning and split of energy levels
13.	Nanoparticles and clusters
14.	Synthesis of nanomaterials with desired bandgap
15.	Top down and bottom up techniques
16.	Synthesis Parameters to control properties of nanoparticles
17.	Characterization techniques for nanoparticles
18.	Jellium Model for molecular structure
19.	Carbon structure, bonding and hybridization
20.	Carbon based materials
21.	Diamond, graphite, Graphene
22.	Fullerene: Evolution and evidence
23.	Structure of C_{60} Fullerene
24.	Properties of C_{60} Fullerene
25.	Synthesis and application of C_{60} Fullerene
26.	Graphene and Carbon nanotubes (CNTs): Historical evidence
27.	Structure and Types of Carbon nanotubes (CNTs)
28.	Thermal and optical Properties of Carbon nanotubes (CNTs)
29.	Mechanical properties of Carbon nanotubes (CNTs)
30.	Synthesis of Carbon nanotubes (CNTs)
31.	Application of CNTs: Hydrogen storage, display and energy harvesting deices
32.	CNT Interconnect in electronic circuits
33.	Formation of Nanotubes, Nanowires, Nanorods, nanoclustures, nanorings
34.	Application of nanomaterials in recent electronic devices
35.	Application of nanomaterials in agriculture and water purification
36.	Drug delivery and nano catalyses
37.	Application of nanomaterials in energy harvesting and pollution control
38.	Micro Electromechanical Systems MEMS
39.	Nano Electromechanical Systems NEMS.
40.	Future for quantum computing
41.	Nanotechnology: Future market
42.	Safety and hazards of nanomaterials

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 1st**	**Year: 2021-22**

Name of Course	**Processing and Fabrication of Nanostructures**
Course Code	**NT-514**
Core / Elective / Other	**Core**

Prerequisite:	
1.	Introducing the students to fundamental of Nanotechnology to control the size of a material for processing and fabrication of nanostructures.
Course Outcomes:	
1.	Students will gain in depth theoretical and practical knowledge on any type of material surface by knowing the processing methods
2.	Students will also learn top down approach to understand the fabrication of nanometer-scale structures.
3.	Student will learn Bottom- up approach to understand the Self-assembly of nanostructures where atoms, molecules or nanoscale building blocks spontaneously organize into ordered structures or patterns with nanometer features without any human intervention.
4.	This course is useful for Electronics, Electrical, Mechanical and Bio-medical engineering Applications
Description of Contents in brief:	
1.	Si processing methods: Cleaning /etching, oxidation-oxides, Gettering, doping, epitaxy. Top-down techniques: Photolithography, other optical lithography, Particle beam lithography, Processing of III-V semiconductors including nitrides. Molecular-Beam Epitaxy, Chemical Beam epitaxy, Metal-Organic CVD. Bottom-up techniques: self-assembly, self-assembled monolayer, directed assembly, layer-by-layer assembly. Combinations of top-down and bottom-up techniques: current state of the art
List of Text Books:	
1.	Hand Book of Semiconductor Cleaning Technology: Werner Kern (William Andrew Publishers)
2.	Principles of Lithography: Harry J. Lavinson, (SPIE Press)
3.	Introduction to Nano Science and Nanotechnology: Chris Binns, (Wiley-VCH)
4.	Self-Assembly and Nanotechnology, A force Balance Approach: Yoon S. Lee (John Wiley & Sons Publication)
List of Reference Books:	
1.	Nanostructrured Materials: Mohinder Seehra (Intech Open Publishers)
2.	Nanostructures:Nejo, Hitoshi (Springer)
3.	G. E. Dieter, adapted by D Bacon, “Mechanical Metallurgy”, SI Metric edition, (McGraw Hill Publishers)
URLs:	
1.	https://www.intechopen.com/books/nanostructured-materials-fabrication-to-applications
2.	https://application.wiley-vch.de/books/sample/3527326758_c01.pdf
3.	https://nptel.ac.in/content/storage2/courses/117104022/Lectures/Lec8.pdf
4.	http://www.cityu.edu.hk/phy/appkchu/AP6120/5.PDF
Lecture Plan (about 40-50 Lectures):	

Lecture No.	Topic
1.	Nanostructures: Fundamentals
2.	Basic idea of Processing and fabrication of materials
3.	Silicon Processing methods: An overview
4.	Preparation of the Silicon Wafer Media
5.	Silicon Wafer Processing Steps
6.	Silicon Wafer Processing Steps (continued)
7.	Cleaning Methods
8.	Etching (Dry & Wet etching)
9.	Oxidation
10.	Gettering (Extrinsic and intrinsic)
11.	Doping
12.	Epitaxy
13.	Top down Approach: Introduction: Types of Lithography process
14.	Photo lithography
15.	Extreme Ultra Voilet Lithography
16.	e-beam lithography
17.	Laser Interference Lithography
18.	Nano-imprint lithography
19.	Idea of compound semiconductors
20.	Processing of III-V group semiconductors
21.	Bonding of silicon and III-V semiconductor materials
22.	Formation of nitride-based semiconductor materials
23.	Introduction of Molecular Beam Epitaxy (MBE)
24.	Sources of Molecular and Atomic Beams
25.	MBE growth process
26.	Material related growth process in MBE
27.	Chemical Beam Epitaxy
28.	Liquid Phase Epitaxy
29.	Fundamentals of Chemical Vapor Deposition Technique
30.	Aspects of Metal organic vapor Phase epitaxy (MOVPE)
31.	Thermodynamics of MOVPE growth
32.	Surface Processes and its effect on material properties
33.	Bottom-up approach: Introduction
34.	Unified approach to Self-Assembly
35.	Intermolecular and colloidal forces
36.	Self-assembled mono layer
37.	Organic Semiconductor for self-assembled monolayer
38.	Self-assembly monolayer structure of Lipids
39.	Layer by Layer self-assembly
40.	Molecular Self Assembly
41.	Combination of Top Down and Bottom-up Approach (continued)
42.	It's Application in nanofabrication
43.	Summary of course (continued)
44.	Summary of course
45.	Recent advances (Current State of Art)

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 1st**	**Year: 2021-22**
Name of Course	**Nanomaterials Synthesis Laboratory**		
Course Code	**NT-515**		
Core / Elective / Other	**Core**		

Prerequisite:

1.	The knowledge of basic magnetism, electricity and semiconductor devices.

Course Outcomes:

Upon successful completion of the course the student will be able to:

1.	Analyze the behavior and characteristics of various materials in different experiments.
2.	Differentiate different materials on the basis of band gap using Four-probe experiment.
3.	Design new nanomaterials using different synthesis techniques
4.	Develop thin film of desired material for engineering.
5.	Develop the skill to observe, analyze and interpret the findings and use the finding to solve engineering problems.

Description of Contents in brief:

1.	To determine Hall Potential and Hall Coefficient of a semiconductor crystal.
2.	To measure resistivity of a semiconductor by Four Probe method at different temperatures and determine the Band-gap.
3.	To determine the spot size, power & beam diversion of the given LASER.
4.	To determine the current-voltage (I-V) characteristics of given conductors and semiconductors
5.	To determine the dielectric constant of solid and liquid
6.	To study the magnetic hysteresis loop of given ferromagnetic materials.
7.	Synthesis of Nano Materials.
8.	Deposition of thin film on glass substrate.

List of Text Books:

1.	Introduction to Solid State Physics: C. Kittel (John Wiley)
2.	Lasers: A. E. Siegman (University Science)
3.	Nanomaterials- An Introduction to Synthesis, Properties and Applications: Dieter Vollath (John Wiley)

List of Reference Books:

1.	Solid State and Semiconductor Physics: J. P. McKelvey (Krieger Publishing Company)
2.	Solid State Physics: S.O. Pillai, (New Age)
3	Laboratory Manual of MANIT Nanomaterials Synthesis Laboratory

URLs:

1.	https://www.youtube.com/watch?v=lUugrqMOY7E
2.	http://vlab.amrita.edu/?sub=1&brch=282&sim=1512&cnt=1
3.	https://www.youtube.com/watch?v=QTyjBigIRkI

4.	https://vlab.amrita.edu/index.php?sub=1&brch=189&sim=342&cnt=1
5.	https://www.youtube.com/watch?v=QTyjBiglRkI

Lab Plan (about 45 Lectures):	
Lecture No.	**Topic**
15x3=45 Periods	15 Labs of 3 periods

Name of Program	**M.Tech. Nanotechnology**	**Semester: 1st**	**Year: 2021-22**

Name of Course	**Communication Skills**
Course Code	**HUM 511**
Core / Elective / Other	**Core**

Prerequisite:	
1.	In order to succeed in this course, the students should have basic knowledge of English language skills and sub-skills
2.	They should have previous knowledge in soft skills and communication and should be able to comprehend advanced technical communication skills in English
3.	The students should also have the ability to adapt to multifarious socio-economical and professional arenas and analyse communicative environments
Course Outcomes:	
1.	On successful completion of this course, postgraduate students will be able to improve their technical communication skills related to listening, Speaking, reading, writing.
2.	The students will be able to organise, comprehend, write, and present short and long forms of any technical work within the broad framework of the scientific method
3.	They will also be able to adhere to ethical norms of scientific communication.
Description of Contents in brief:	
1.	**Unit I: Scientific Method and its Relationship to Technical Communication** Basics of technical communication, Formulation of hypothesis, Paragraph organisation, Argument development, Evidence and elaboration
2.	**Unit II: Listening and Reading Skills** Note taking, Survey of literature, Different reading strategies
3.	**Unit III: Writing Skills** Report writing, Peer review skills, Summary and abstract writing, Bibliography and references, Data Analysis and Presentation, Visual communication
4.	**Unit IV: Speaking Skills** Elevator pitch, Oral presentation, Slides for presentation, Group discussions, Interview skills
5.	**Unit V: Ethics in Communication** Ethics in education and research, Copyrights and plagiarism, Authorship, Gender and diversity, Net etiquettes and workplace communication
List of Text Books:	
1.	Arora, V.N., and Lakshmi Chandra. Improve your Writing. 1981. New Delhi: Oxford UP, 2001.
2.	Graff Gerald, and Birkenstein Cathy. “They Say I Say”-The Moves That Matter in Academic Writing. W.W.Norton and Company. Fourth edition. 2018
3.	Lesikar, Raymond V and Marie E. Flatley. Basic Business Communication: Skills for Empowering the Internet Generation: Ninth Edition. New Delhi: Tata McGraw-Hill Publishing Company Ltd., 2002.
List of Reference Books:	
1.	Graff Gerald, and Birkenstein Cathy. “They Say I Say”-The Moves That Matter in Academic Writing. W.W. Norton and Company. Fourth edition. 2018
2.	Kumar Sanjay, and Lata Pushp. Communication Skills. 2011. Oxford University Press,

	2015
3.	Raman Meenakshi, and Sharma Sangeeta. Technical Communication: Principles and Practice. 2015. Oxford University Press, 2015
URLs:	
1.	https://nptel.ac.in/courses/109/105/109105110
2.	https://nptel.ac.in/courses/109/105/109105117
3.	https://nptel.ac.in/courses/109/104/109104115

Lecture Plan (about 40-50 Lectures):

Lecture No.	**Topic**
1-2	Basics of technical communication
3	Formulation of hypothesis
4-5	Paragraph organisation
6	Argument development
7	Evidence and elaboration
8	Note taking
9-10	Survey of literature
11	Different reading strategies
12-13	Report writing
14-16	Peer review skills
17-18	Summary and abstract writing
19-20	Bibliography and references
21-25	Data Analysis and Presentation
26-27	Visual communication
28	Elevator pitch
29-33	Oral presentation
34	Slides for presentation
35-37	Group discussions
38-40	Interview skills
41	Ethics in education and research
42-43	Copyrights and plagiarism
44	Authorship
45	Gender and diversity
46	Net etiquettes
47- 48	Workplace communication

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 1st/2nd**	**Year: 2021-22**

Name of Course	**Photonic Materials**
Course Code	**NT-553**
Core / Elective / Other	**Elective (A)**

Prerequisite:

1.	Basic quantum mechanics, magnetism and electromagnetic waves

Course Outcomes: At the end of the course, the student will be able to:

1.	Apply the scientific knowledge gained through the subject to attain problems related to engineering
2.	Differentiate ferromagnetic, anti-ferromagnetic and ferrimagnetic order on the basis of exchange integral
3.	Outline the magnetic excitations in nanoparticles
4.	Propose new areas of research in nanotechnology and allied fields of LASER
5.	Explain the trapping and cooling of atoms by radiation forces

Description of Contents in brief:

1.	**Photonic materials:** Atomic scale structure of materials
2.	**Magnetism:** moments, environments and interactions, order and magnetic structure
3.	**Scattering theory:** Excitations of crystalline materials, magnetic excitations, sources of X-rays and neutrons
4.	**Interaction of light with photon:** LASER Chaotic light and coherence. Laser spectroscopy. Multiphoton processes. Light scattering by atoms. Electron scattering by atoms. Coherence and cavity effects in atoms. Trapping and cooling

List of Text Books:

1.	Nanoscale Multifunctional Materials: Science and Applications, Sharmila M. Mukhopadhyay, (Wiley)
2.	Light and Matter: Electromagnetism, Optics, Spectroscopy and Lasers, Yehuda B. Band, (Wiley)
3.	Nanostructured Films & Coatings, Gang Moog Chow, (Springer)
4.	Solid State Properties: From Bulk to Nano, Mildred Dresselhaus, Gene Dresselhaus, et al., (Springer)

List of Reference Books:

1.	Introduction to Molecular Magnetism: From Transition Metals to Lanthanides, Cristiano Benelli and Dante Gatteschi, (Wiley)
2.	Magnetism in Condensed Matter, Stephen Blundell, (Oxford University Press)
3.	Introduction to Magnetic Materials, By B. D. Cullity and C. D. Graham (Wiley)

URLs:

1.	https://nptel.ac.in/courses/118/106/118106021/
2.	https://swayam.gov.in/nd1_noc20_mm19/preview
3.	https://nptel.ac.in/courses/118/102/118102003/
4.	https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=28
5.	https://swayam.gov.in/nd1_noc20_cy23/preview

Lecture Plan (about 40-50 Lectures):

Lecture No.	**Topic**
Lecture 1	Overview: Photonics-Materials
Lecture 2	Crystallinity of materials (polycrystalline, amorphous, single crystal)

Lecture 3	Bulk and Nano materials
Lecture 4	Defects: 3D, 2D, 1D and 0D
Lecture 5	Analysis of crystalline materials (XRD, TEM and AFM)
Lecture 6	Tutorial/case study on structure of materials
Lecture 7	Magnetism: magnetic moment
Lecture 8	Einstein de- Haas effect (Origin of magnetism)
Lecture 9	Inverse Einstein de- Haas effect
Lecture 10	Case study on orbital angular momentum and magnetism
Lecture 11	Exchange interaction
Lecture 12	Dirac- Heisenberg interaction, Exchange integral, Coulomb integral
Lecture 13	Ferrimagnetic order, Ferromagnetic domains
Lecture 14	Antiferromagnetic and Ferrimagnetic order
Lecture 15	Direct exchange and Indirect exchange interaction
Lecture 16	Super exchange interaction
Lecture 17	Tutorial/case study on exchange interaction
Lecture 18	Scattering theory: Excitations of crystalline materials
Lecture 19	Magnetic excitation, Spin waves
Lecture 20	Magnons, magnon dispersion relation
Lecture 21	Case study on spin waves
Lecture 22	Thermal excitation of magnons
Lecture 23	Neutron magnetic moment
Lecture 24	Anisotropy energy, Transition region between domains
Lecture 25	Origin of domains, coercivity and hysteresis
Lecture 26	Single domain particle, Magnetic bubbles domains
Lecture 27	Crystal Field splitting
Lecture 28	Sources of X-rays
Lecture 29	Sources of neutrons
Lecture 30	Case study on crystal field
Lecture 31	Interaction of light with matter
Lecture 32	LASER Process
Lecture 33	Working Principal of LASER, LASER spectroscopy
Lecture 34	Coherence and Chaotic light
Lecture 35	Multiphoton process
Lecture 36	Tutorial/ case study on LASER
Lecture 37	Light scattering by atoms, electronic polarization
Lecture 38	Raman scattering
Lecture 39	Thomson scattering
Lecture 40	Electron scattering by atoms (electron-atom interaction)
Lecture 41	Electron-molecules scattering
Lecture 42	Elastic and inelastic scattering
Lecture 43	Electronic excitation, Kikuchi lines
Lecture 44	Case study on interaction between light-atoms & electron-atoms
Lecture 45	Cavity Field in Coherent State and thermal state
Lecture 46	Trapping and cooling of atoms
Lecture 47	Tutorial/case study on LASER cooling

Name of Program	**M.Tech. Nanotechnology)**	**Semester: 1st/2nd**	**Year: 2021-22**

Name of Course	**Nanoelectronics**
Course Code	**NT-567**
Core / Elective / Other	**Elective (A)**

Prerequisite:	
1.	Knowledge of basic Physics and Quantum Mechanics.
2.	Knowledge of Mathematical Differentiation and Integration.
Course Outcomes: At the end of the course, the student will be able to:	
1.	Explain the effects of quantum confinement on the electronic structure and corresponding physical and chemical properties of materials at nanoscale.
2.	Explain the concepts of a quantum well, quantum transport and tunneling effects and quantum mechanics behind nanoelectronics.
3.	Describe the spin-dependent electron transport and the mechanism of data storage in memory devices.
4.	Explain the structure and function of liquid crystal displays and devices.
5.	Apply their learned knowledge to develop Nanomaterial's for engineering problems.
Description of Contents in brief:	
1.	**Spintronic:** Spin Injection, GMR & TMR, Spin valve effect, spin valves and MRAM devices
2.	**Solid state devices**: quantum dots, quantum wires, quantum well
3.	**Nanophotonics:** Photonic bandgap materials, nanoscale photonic devices, Special phenomena in 2D and 3D nano structures
4.	**Liquid crystals:** The basic properties of liquid crystals and their display and non-display applications at the nanoscale.
List of Text Books:	
1.	Nano Electronics and Information Technology: Rainer Waser (John Wiley)
2.	Nanoelectronics Principles and Devices: M. Dragoman & D. Dragoman (Artech House Publishers)
List of Reference Books:	
1.	Fundamentals of Nanoelectronics: George W. Hanson (Pearson)
2.	Introduction to Nanoelectronics Science, Nanotechnology, Engineering, and Applications: V. V. Mitin& V. A. Kochelap (Cambridge University Press)
3.	Integrated Electronics Analog and digital Circuit: J Millman & C.C. Halkias (Tata McGraw-Hill)
4.	Nano-Electronic Devices Semiclassical and Quantum Transport Modeling: D. Vasileska& S.M. Goodnick (Springer)
5.	Introduction to quantum mechanics: D. J. Griffiths (Prentice Hall)
6.	Photonics: Nanophotonic Structures and Materials: David L Andrews (Wiley)
7.	Liquid Crystals: Iam-Choon Khoo (Wiley)
URLs:	
1.	https://nptel.ac.in/courses/117/108/117108047/
2.	https://nptel.ac.in/courses/118/104/118104008/
3.	https://www.youtube.com/watch?v=wdNFCWLuC10&list=PLbMVogVj5nJT8RG5Q4CpsJXiGqXE6t8N1
4.	https://www.youtube.com/watch?v=RnUGSDW-Tfk

Lecture Plan (about 40-50 Lectures):

Lecture No.	**Topic**
Lecture 1	Introduction to syllabus
Lecture 2	Quantum Mechanics: electrons in one atom, wave function
Lecture 3	Schrödinger equation, eigenfunctions, quantum numbers,
Lecture 4	Superposition of eigenfunctions, probability densities
Lecture 5	Spin physics in solids, Electron's angular momentum and spins
Lecture 6	Spin relaxation mechanisms, spin-orbit interaction.
Lecture 7	Spin coherence in semiconductors, spin polarized current
Lecture 8	Spin dependent electronic transport: spin diffusion, spin injection
Lecture 9	Tutorial/case study on Quantum mechanics and Spin injection
Lecture 10	Origin of resistance
Lecture 11	Magnetoresistance, spin dependent scattering
Lecture 12	Giant magnetoresistance (GMR)
Lecture 13	Tunneling of electron, spin dependent tunneling
Lecture 14	Tunnel magnetoresistance (TMR)
Lecture 15	Tutorial/case study on Magnetoresistance
Lecture 16	Spin valve effect
Lecture 17	Data storage devices, random access memory (RAM)
Lecture 18	Magnetoresistive random access memory (MRAM)
Lecture 19	Reading and writing process in MRAM
Lecture 20	Spin-transfer torques (STT), spin-transfer torques-RAM,
Lecture 21	Endurance, data retention
Lecture 22	Tutorial/Case study/Group discussion on data storage device
Lecture 23	Introduction to Nanostructure: Classification of nanostructures
Lecture 24	Tuning of band gap at nanoscale, quantum confinement, size effects
Lecture 25	Quantum dots (0 D)
Lecture 26	Quantum wire (1 D)
Lecture 27	Quantum well (2 D)
Lecture 28	Density of state calculation of 0D, 1D and 2 D nanostructures
Lecture 29	Tutorial/case study/group discussion on nanostrucutres
Lecture 30	Photonic bandgap
Lecture 31	Photonic bandgap materials
Lecture 32	Defects in photonic crystals, localization of light,
Lecture 33	Nanoscale photonic devices
Lecture 34	Special phenomena in 2D, 3D nanostructures
Lecture 35	Tutorial/case study on Photonic bandgap
Lecture 36	Introduction of Liquid crystal, Properties of liquid crystal (LC)
Lecture 37	Classification of LC: lyotropic, nematic and smectic
Lecture 38	Application of LC in Display Devices
Lecture 39	Application of LC in Non-Display Devices
Lecture 40	Working of Liquid Crystal Display
Lecture 41	Working of Non-Display Devices
Lecture 42	Tutorial/case study on Liquid Crystal

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 1st/2nd**	**Year: 2021-22**

Name of Course	**Low Temperature Behavior of Materials**
Course Code	**NT-559**
Core / Elective / Other	**Elective (A)**

Prerequisite:

1.	Fundamentals and applications of forced vibrations, resonance, and its energy, gas laws with their applications. Laws of thermodynamics and its importance in engines efficiency.

Course Outcomes:

1.	This paper is useful to learn essential theoretical elements and the principal measurement methods to understand the magnetic and thermal properties of the materials which will be useful in research and development of cryogenic technology.

Description of Contents in brief:

1.	Thermodynamics & liquefaction of gases, Cryostat design, Transport Phenomenon, Fermi surface, Magnetism.
2.	Conductivity of solids, Technique of measurement, Paramagnetic & Nuclear adiabatic demagnetization. Superconductivity. Fundamental phenomena of super conductivity, Meissner effect, London equation, Type I and Type II superconductors, qualitative idea of Cooper pairing and BCS theory.
3.	Ginsburg-Landau theory, coherence length, Green's functions of electrons and phonons, isotope effect, The BCS Hamiltonian, the gap parameter, Superconductor in a field, flux quantization effect, SQUIDS, High-T_c materials

List of Text Books:

1.	Superconductivity: Werner Buckel& Reinhold (Wiley-VCH)
2.	Thermodynamics: M.S.Yadav (ANMOL PUBLICATIONS)
3.	Thermodynamics:Enrico Fermi (Dover Publications, INC.Mineola New York)

List of Reference Books:

1.	Introduction to Superconductivity by A C Rose-Innes and E H Rhoderick (Elsevier)
2.	Handbook of Superconducting Materials: David A. Cardwell, David S. Ginley (Institute of Physics Publishing Limited)
3.	Introduction to Superconductivity: Michael Tinkham (Dover Publications, INC.Mineola New York)

URLs:

1.	https://nptel.ac.in/courses/115101012/
2.	https://nptel.ac.in/courses/112/101/112101004/
3.	https://nptel.ac.in/content/storage2/courses/113106062/Lec7.pdf
4.	https://nptel.ac.in/courses/112108148/
5.	https://nptel.ac.in/courses/112105266/

Lecture Plan (about 40-50 Lectures):

Lecture No.	Topic
1.	Thermodynamics: Introduction, Legendre's Polynomials, Thermodynamic potentials

2.	Laws of thermodynamics
3.	Applications of laws of Thermodynamics, Entropy of the system
4.	Thermodynamic relations, Carnot's theorem, Gibbs-Durem Equation
5.	Liquefaction of gases, Joule- Thomson effect, Kinetic Theory of Gases
6.	Introduction- Liquefaction of gases, Principles - Liquefaction of gases
7.	Liquefaction of gases methods
8.	Cryostat Design: Cryostat introduction, Cryostat Design: Cryostat components
9.	Transport Phenomenon: Modes
10.	Transport Phenomenon: Types, mechanism
11.	Conduction, Convection and Radiation
12.	Elementary particles, Fermi level, Fermi surface, Fermi temperature
13.	Magnetism.: Introduction, Gauss's law.
14.	Magnetic moment, Numerical Problems.
15.	Electron in magnetic field, Numerical Problems
16.	Diamagnetism, Para magnetism, Numerical Problems
17.	Ant ferromagnetism, Ferrimagnetisms
18.	Demagnetization
19.	Nuclear adiabatic demagnetization
20.	Magnetic materials
21.	Conductivity of solids
22.	Technique of measurement
23.	Paramagnetic & Nuclear adiabatic demagnetization
24.	Superconductivity
25.	Fundamental phenomena of super conductivity
26.	Meissner effect
27.	London equation
28.	Type I and Type II superconductors: Introduction
29.	Type I and Type II superconductors Properties
30.	Type I and Type II superconductors applications
31.	BCS theory
32.	Qualitative idea of Cooper pairing
33.	Ginsburg-Landau theory
34.	Coherence length
35.	Green's functions of electrons and phonons
36.	The BCS Hamiltonian
37.	The gap parameter
38.	Superconductor in a field
39.	Applications of Superconductivity
40.	Isotope effect

Name of Program	**M.Tech. Nanotechnology)**	**Semester: 1st/2nd**	**Year: 2021-22**
Name of Course	**Solar Photovoltaic Technology**		
Course Code	**NT-568**		
Core / Elective / Other	**Elective (A)**		

Prerequisite:	
1.	Familiarity with basics of Quantum Mechanics
Course Outcomes:	
1.	Students will be able to understand photovoltaic systems, applications for photovoltaic systems Identify practices and protective equipment used for PV systems.
Description of Contents in brief:	
1.	The Sun Light: World Energy scenario-Advantages and challenges of solar energy harnessing, Source of radiation, solar constant, solar intensity at earth's surface, direct and diffuse radiation, apparent motion of sun, solar insolation data, solar charts, measurement of diffuse, global and direct solar radiation: pyrheliometer, pyranometer, pyregeometer, net pyradiometer, sunshine recorder. Semiconductors for Solar Cell: Silicon:preparation of metallurgical, electronic and solar grade silicon, Production of single crystal silicon:Czokralski (CZ) and Float Zone (FZ) method, imperfections, carrier doping and lifetime, Germanium, compound semiconductors, growth & characterization, amorphous materials, transparent conducting oxides, anti-reflection principles and coatings, organic materials. Characterization and Analysis: Device isolation & analysis, ideal cell under illumination, solar cell parameters short circuit current, open circuit voltage, fill factor, efficiency; optical losses, electrical losses, surface recombination velocity, quantum efficiency, measurements of solar cell parameters; I-V curve & L-I-V characteristics, internal quantum yield measurements, effects of series and parallel resistance and temperature.
List of Text Books:	
1.	Solar Photovoltaics: Fundamentals, Technologies and Applications, Chetan Singh Solanki,
2.	Solar Cells and their Applications: Larry D. Partain (ed.), (John Wiley and Sons)
3.	The Physics of Solar Cells: J. Nelson, (Imperial College Press)
4.	Photovoltaic Materials, R. H. Bube, (Imperial College Press)
List of Reference Books:	
1.	Photovoltaic Systems: Jim Dunlop (An American Technical Publishers, INC. publication)
2.	Photovoltaic Systems:National Joint Apprenticeship and Training (Amer Technical Pub;)
3.	Physics of Solar Cells: Peter Würfel, UliWürfel (Wiley-VCH)
URLs:	
1.	https://nptel.ac.in/courses/115/107/115107116/
2.	http://energy.mit.edu/news/solar-photovoltaic-technologies/
3.	https://nptel.ac.in/content/storage2/courses/113106065/Week%208/Lesson19.pdf
4.	https://nptel.ac.in/courses/113/106/113106062/
5.	https://nptel.ac.in/content/storage2/courses/117101054/downloads/lect9.pdf

Lecture Plan (about 40-50 Lectures):

Lecture No.	**Topic**
1.	Energy and its sources
2.	Introduction to Solar energy

3.	Introduction to Photovoltaic Systems
4.	Introduction of quantum mechanics in Photovoltaic Systems
5.	The Sun Light: World Energy scenario: Advantages & challenges of solar energy harnessing
6.	Advantages and challenges of solar energy
7.	harnessing - Source of radiation
8.	Solar constant– solar intensity at earth’s surface -direct and diffuse radiation
9.	Review of Semiconductor Physics, Charge carrier generation and recombination, p-n junction model and depletion capacitance, Current voltage characteristics in dark and light
10.	Apparent motion of sun-solar insolation data –solar charts
11.	Measurement of diffuse, global and direct solar radiation
12.	Advantages and challenges of solar energy
13.	Pyrheliometer
14.	Pyranometer
15.	Charge carrier dynamics in semiconductors
16.	Pyregeometer
17.	Net pyradiometer-sunshine recorder.
18.	Semiconductors for Solar Cell: Silicon*:*
19.	Preparation of metallurgicalSilicon:
20.	Preparation of electronic and solar grade silicon
21.	Preparation of solar grade silicon
22.	Production of single crystal silicon:Czokralski (CZ) method
23.	Float Zone (FZ) method
24.	Czokralski (CZ) and Float Zone (FZ) method- imperfections
25.	Czokralski (CZ) and Float Zone (FZ) method-carrier doping and lifetime
26.	Production of single crystal silicon:Czokralski (CZ) and Float Zone (FZ) method lifetime
27.	Germanium-compound semiconductors-growth
28.	Germanium-compound semiconductors-characterization
29.	Germanium-compound semiconductors-growth & characterization-amorphous materials
30.	Germanium-compound semiconductors-growth & characterization-transparent conducting oxide
31.	Anti-reflection principles and coatings.
32.	Anti-reflection principles and coatings-organic materials.
33.	Transparent conducting oxides-anti-reflection principles and coatings-organic materials. Characterization and Analysis
34.	Ideal cell under illumination
35.	Solar cell parameters. short circuit current, open circuit voltage, fill factor, efficiency
36.	Optical losses, electrical losses, surface recombination velocity.
37.	Quantum efficiency-measurements of solar cell parameters; I-V curve& L-I-V characteristics
38.	Internal quantum yield measurements
39.	Effects of series and parallel resistance and temperature
40.	Applications of Photovoltaic Systems

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Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 2nd**	**Year: 2021-22**

Name of Course	**Nanostructure Characterization Techniques**
Course Code	**NT-521**
Core / Elective / Other	**Core**

Prerequisite:	
1.	Disseminate the practical knowledge to students on various types of Nanostructure Characterization Techniques to analyze nanoscale surfaces.
Course Outcomes:	
1.	Students will gain in depth theoretical and practical knowledge on any type of material surface by knowing the mechanism of various compositional surface Analysis techniques.
2.	Students will also learn about morphologic, compositional and crystallographic information on samples.
3.	To gain a better understanding of the storage mechanism, the study of photoluminescence and cathodoluminescence is fruitful.
4.	Gaining knowledge of probe techniques which are useful in making images of nanoscale surfaces and structures, including atoms.
5.	Brandish knowledge of nanoscale I-V and C-V relationships.
6.	This course is useful for Electronics, Electrical, Mechanical and Bio-medical engineering Applications
Description of Contents in brief:	
1.	Compositional surface analysis: Ultraviolet (UV) and X-ray photoelectron spectroscopy (XPS), Secondary ion mass spectrometry (SIMS), Contact angles Microscopies: Optical microscopy, Fluorescence & Confocal microscopy, Cathodoluminescence (CL) and photoluminescence (PL) ,TEM, SEM. Probe techniques: Atomic force microscopy (AFM), scanning tunneling microscopy (STM), scanning near field optical microscopy (SNOM), Deep level transient spectroscopy (DLTS), Kelvin-probe measurements. Nanoscale current-voltage (I-V), capacitance-voltage (C-V) relationships.
List of Text Books:	
1.	Fundamentals of Nano Scale Film Analysis: Alford, Feldman, Mayer (Springer)
2.	Nano Structured Materials: Carl C. Koch (William Andrew Publisher)
3.	Nanostructures & Nano Materials: Ghuzang Cao (World Scientific Publishing Company)
4.	Hand Book of Nanophase& Nanomaterials: Zhong Lin Wang (Springer) (Vol. I&II)
List of Reference Books:	
1.	Nano/Micro-Structured Materials for Energy and Biomedical Applications: Bingbing Li and Tifeng Jiao (Springer)
2.	Semiconductor Photonics: Nano-Structured Materials and Devices: S. J. Chua,J. H. Teng, O. Wada, R. De La Rue , X. H. Tang (Trans Tech Publications, Ltd.)
3.	Handbook of Instrumentation and Techniques for Semiconductor Nanostructure Characterization:Richard Haight, Frances M Ross, James B Hannon (World Scientific Publishing Company)
URLs:	
1.	https://nptel.ac.in/courses/118/104/118104008/
2.	https://nptel.ac.in/courses/115/103/115103030/

3.	http://folk.uio.no/yurig/Nanotechnology/Student_presentations/2014/DLTS-Nanophysics-2014.pdf
4.	https://www.ripublication.com/ijpap17/ijpapv13n1_15.pdf
5.	https://nptel.ac.in/courses/113/106/113106064/

Lecture Plan (about 40-50 Lectures):

Lecture No.	**Topic**
1.	Brief idea of Nanostructures
2.	Compositional Surface Analysis and its importance
3.	Surface Analysis Techniques: An overview
4.	X-ray Photoelectron Spectroscopy (XPS) (continued)
5.	Principle of XPS (continued)
6.	Preparing and Mounting Samples (continued)
7.	Experimental Procedure and Data Interpretation
8.	Secondary ion mass spectrometry (SIMS), (continued)
9.	Static SIMS (continued)
10.	Dynamic SIMS (continued)
11.	Experimental Procedure (continued)
12.	Time of Flight (ToF) SIMS
13.	Contact angles
14.	Optical Microscopy: An introduction
15.	Fluorescence
16.	Confocal Microscopy
17.	Luminescence and its types
18.	Cathodoluminescence
19.	Photoluminescence
20.	Scanning Electron Microscope (SEM), Principal and Experimental Procedure (Continued)
21.	Image formation
22.	Transmission Electron Microscope (TEM), Principal and Experimental Procedure (Continued)
23.	Formation of Diffraction Pattern and the image in the TEM
24.	Probe Technique: An introduction to Scanning Probe Microscopy
25.	Atomic Force Microscope (AFM) (Continued)
26.	Tip Sample interaction and Feedback Mechanism (Continued)
27.	Atomic Force and different scanning modes (Continued)
28.	AFM tips and resolution
29.	Principle of Scanning Tunneling Microscope (Continued)
30.	Experimental procedure and Image formation
31.	Scanning Near Field Optical Microscopy (SNOM) (Continued)
32.	Mechanism of SNOM (Continued)
33.	Different scanning mode and Systems of SNOM
34.	Deep level transient spectroscopy (DLTS), (Continued)
35.	Extraction of defect properties
36.	Kelvin-Probe Force Microscopy (KPFM) (Continued)
37.	Electrostatic Models; Single Charge Trapped within a Capacitor (Continued)

38.	Assemblies of Charge on a bulk insulator
39.	Nanoscale current-voltage (I-V),
40.	Point contact Current -Voltage Characteristics
41.	Capacitance-voltage (C-V) relationships
42.	Summary of course (continued)
43.	Summary of course
44.	Recent advances (Current State of Art)

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 2nd**	**Year: 2021-22**
Name of Course	**Properties of Low-dimensional System**		
Course Code	**NT-522**		
Core / Elective / Other	**Core**		

Prerequisite:

1.	Basic quantum mechanics, semiconductor and electromagnetic waves

Course Outcomes: At the end of the course, the student will be able to:

1.	Classify the n and p-type of carrier concentration on the basis of Hall coefficient
2.	Recognize the importance of density of states for various day-to-day applications in device fabrication
3.	Examine the behavior of conductor, semiconductor and superconductor at very low temperatures
4.	Implement the knowledge of energy matter interaction to get the information about the symmetry of molecules
5.	Explain the nature of inter particle interaction

Description of Contents in brief:

1.	**Transport properties:**quantization of conductance, density of states, Coulomb blockade, Kondo effect. Hall, quantum Hall, fractional quantum hall effects
2.	**Vibrational and thermal properties:**phonons, quantization of phonon modes, heat capacity and thermal transport
3.	**Optical properties:**Collective oscillation (Gustav-Mie explanation), surface plasmon resonance, interactions between nanoparticles, coupled-dipole approximation, Linear and Nonlinear optical properties.

List of Text Books:

1.	Physics of Low Dimensional Systems, J.L. Moran-Lopez, (Springer)
2.	Properties of Interacting Low-Dimensional Systems, Godfrey Gumbs, (Wiley)
3.	Nano optoelectronics, M. Grundman, (Springer)
4.	Handbook of Nanotechnology, Bhushan, (Springer)
5.	Nanophotonics, Paras N. Prasad, (Wiley)

List of Reference Books:

1.	Kondo Effect and Dephasing in Low-Dimensional Metallic Systems, Venkat Chandrasekhar (Springer)
2.	Molecular Vibrations: The Theory of Infrared and Raman Vibrational Spectra, E. Bright Wilson, (Dover)

URLs:

1.	https://nptel.ac.in/courses/118/102/118102003/
2.	https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=28
3.	https://nptel.ac.in/courses/118/106/118106021/
4.	https://swayam.gov.in/nd1_noc20_mm19/preview

Lecture Plan (about 40-50 Lectures):

Lecture No.	Topic
Lecture 1	Transport properties: Quantum conductance
Lecture 2	Fermi wavelength, resistivity in 2D materials
Lecture 3	Quantum point contact
Lecture 4	Density of states: electron density of states, Dispersion relation
Lecture 5	Energy of a quantum particle, Fermi Dirac Distribution function, Fermi energy
Lecture 6	Electron concentration in metals, density of states for bulk (3D materials)
Lecture 7	Density of states for quantum well (2D materials),
Lecture 8	Density of states for quantum wire (1D materials), Density of states for quantum dot (0D materials)
Lecture 9	Tutorial/ case study on density of states
Lecture 10	Coulomb blockade: single electron transistor
Lecture 11	Capacitance, Stored energy in capacitor, Finite time
Lecture 12	Heisenberg uncertainty, MOSFET
Lecture 13	Kondo effect: Resistivity, Quantum impurities (Magnetic impurities)
Lecture 14	Low temperature behavior of resistivity in metal, Semiconductor, Superconductor
Lecture 15	Tutorial/ case study on material properties below room temperature
Lecture 16	Hall effect
Lecture 17	Integer quantum Hall effect,
Lecture 18	Devices used for observing the quantum Hall effect
Lecture 19	Landau levels in a crystal, Quantum mechanical interpretation
Lecture 20	Effects of the electron spin, Fractional Quantum Hall Effect
Lecture 21	Tutorial/ case study on Hall effect
Lecture 22	Vibrational and thermal properties: phonons
Lecture 23	Quantization of elastic waves, Phonon momentum
Lecture 24	Vibrational energy and its quantum picture
Lecture 25	Determination of shape and orientation of particles
Lecture 26	Tutorial/ case study on vibration of molecules
Lecture 27	An-harmonic vibration
Lecture 28	Raman Active molecules
Lecture 29	Infrared active molecule
Lecture 30	Carbon nanotube, Thermal conductivity, Thermoelectric power
Lecture 31	Heat capacity of nanomaterials
Lecture 32	Thermal expansion, Normal mode enumeration
Lecture 33	An-harmonic crystal interaction
Lecture 34	Tutorial/ case study on internal energy of the system
Lecture 35	Optical properties: Collective oscillation (Gustav-Mie explanation), Interaction of a photonic with a macroscopic particle
Lecture 36	Frequency-domain scattering by a particle, Mie's scattering concept, Optical absorption and transmission
Lecture 37	Principle of surface plasmon resonance
Lecture 38	Methods of surface plasmon excitation
Lecture 39	Tutorial/ case study on interaction of electromagnetic wave with atoms
Lecture 40	Detection of dengue NS1 antigen using LRSPP, Detection of pregnancy associated plasma protein, Detection of breast cancer antigen
Lecture 41	Electrostatic Interactions between nanoparticles
Lecture 42	Magnetic Interactions between nanoparticles

Lecture 43	Impact of Au nanoparticles/ carbon nanotube on the immune system
Lecture 44	Linear and non-linear optical properties of Si quantum dot
Lecture 45	Kerr effect, Linear and non-linear photo absorption and refractive index
Lecture 46	Dielectric confinement
Lecture 47	Melt-quenching technique, Colloidal chemical synthesis
Lecture 48	Tutorial/ case study on linear and non-linear properties of molecules

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 2nd**	**Year: 2021-22**

Name of Course	**Instrumentation**
Course Code	**NT-523**
Core / Elective / Other	**Core**

Prerequisite:

1.	Basic knowledge of Materials Science & Engineering

Course Outcomes:

1.	In-depth knowledge about instruments used for different characterization techniques
2.	Study of theory, construction and working mechanism of instruments used for understanding electrical, ferroelectric and dielectric properties of materials, electrochemical properties of materials
3.	Detailed study of instruments used for Electron micrography, phase identification, Spectrophotometry
4.	Understanding the techniques like NMR, ESR, FTIR, Raman for nanostructure characterization
5.	Uses and applications of different types of Vacuum gauges and thin film thickness monitor

Description of Contents in brief:

1.	Electrical & thermal properties measurements: Resistivity, dielectric, thermoelectric, specific heat, Hall effect, Ferroelectric, Piezoelectric, Pyroelectric properties. Magnetic properties: VSM, SQUIDS, MFM, Susceptibility, Magneto-optical Kerr effect. Thermal analysis: TGA-DTA, DSC. Vacuum pumps (Turbo and ultra-high vacuum), Measurement of Low pressure - penning and pirani gauge. Film thickness measurement. Compositional analysis: Electron probe micro analysis (EPMA), Auger electron spectroscopy (AES), Inductive coupled plasma-mass spectroscopy (ICP-MS). Spectroscopic techniques: UV-VIS, NMR, ESR, Ferromagnetic resonance (FMR), Raman Spectroscopy, FTIR. Particle analysis: Dynamic light scattering (DLS), BET surface area analyzer. Small Angle X-ray Scattering, X-ray absorption spectroscopy (XAFS, XANES), Electrochemical impedance spectroscopy.

List of Text Books:

1.	Handbook of Analytical Instruments: R. S. Khandpur (McGraw Hill)
2.	A Textbook of Nanoscience and Nanotechnology:P. I. Varghese, T. Pradeep (McGraw Hill)
3.	Spectroscopic Methods for Nanomaterials Characterization: Sabu Thomas, Raju Thomas, Ajesh K. Zachariah, Raghavendra Kumar Mishra (Elsevier)
4.	Microscopy Methods in Nanomaterials Characterization:Sabu Thomas, Raju Thomas, Ajesh K. Zachariah, Raghavendra Kumar Mishra (Elsevier)
5.	Principles of Nanomagnetism,Alberto P. Guimarães (Springer)
6.	Differential Scanning Calorimetry: An Introduction for Practitioners:G.W.H. Höhne, W. Hemminger (Springer)
7.	Characterization of Porous Solids and Powders: Surface Area, Pore Size and Density: S. Lowell, Joan E. Shields, Martin A. Thomas, Matthias Thommes (Springer)

List of Reference Books:

1.	Analytical Instrumentation Handbook: Jack Cazes and Jack Cazes (CRC Press)
2.	Elements of X-ray Diffraction, B. D. Culity (Pearson, UK)
3.	Introduction to magnetic materials, B. D. Culity (Wiley)

4.	Handbook of Thin Film Technology: Leon I. Maissel, R. Glang (McGraw Hill)
5.	Thermal Methods of Analysis: W. W. Wendland (Wiley-Blackwell)
6.	X-Ray Absorption and X-Ray Emission Spectroscopy: Theory and Applications: Jeroen A. Van Bokhoven, Carlo Lamberti (Wiley)
7.	Ferroelectrics: Principles and Applications, Ashim Kumar Bain, Prem Chand (Wiley)
8.	Handbook of Vacuum Technology,Karl Jousten (Wiley)
9.	Miniaturization and Mass Spectrometry: Severine le Gac, Albert van den Berg (Royal Society of Chemistry)
10.	Thermal Analysis Techniques and Application: E. L. Charsley, & S. B. Warrington (Royal Society of Chemistry)
11.	Thermal Analysis: Fundamentals and Applications to Polymer Science, T. Hatakeyama. & F. X. Quinn (John Wiley & Sons)
12.	Impedance Spectroscopy: Theory, Experiment, and Applications, EvgenijBarsoukov, J. Ross Macdonald (John Wiley & Sons, Inc.)
URLs:	
1.	https://web.njit.edu/~tyson/PPMS_Documents/PPMS_Manual/1070-150%20Rev.%20B5%20PQ%20%20PPMS%20Hardware.pdf
2.	http://four-point-probes.com/four-point-probe-manual/
3.	https://nptel.ac.in/courses/118/104/118104008/
4.	https://nptel.ac.in/courses/113/107/113107081/
5.	https://physlab.lums.edu.pk/images/e/eb/Reframay4.pdf
6.	http://academy.cba.mit.edu/classes/input_devices/meas.pdf
7.	https://www.iucr.org/education
8.	https://www.rrcat.gov.in/technology/accel/srul/beamlines/exafs.html#intr
9.	http://csr.res.in/indore_centre_facilities_link_page1.html
10.	https://crimsonpublishers.com/mapp/pdf/MAPP.000509.pdf
11.	https://nptel.ac.in/courses/113106064/
12.	https://nptel.ac.in/content/storage2/courses/112108150/pdf/PPTs/MTS_16_m.pdf
13.	https://nptel.ac.in/courses/115103030/
14.	https://www.elsevier.com/data/promis_misc/622954sc1.pdf
15.	https://www.iitk.ac.in/ibc/Vacuum_Gauges.pdf
16.	https://www.ferrodevices.com/1/297/files/Ferroelectric_Properties_and_Instrumentation(1).pdf
17.	https://www.horiba.com/en_en/raman-imaging-and-spectroscopy/
18.	https://www.lehigh.edu/imi/teched/GlassCSC/SuppReading/Tutorials.pdf
19.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2777224/
20.	https://www.gamry.com/application-notes/battery-research/testing-electrochemical-capacitors-cyclic-voltammetry-leakage-current/
21.	https://www.shimadzu.com/an/uv/support/uv/ap/film.html
22.	https://www.jawoollam.com/resources/ellipsometry-tutorial

Lecture Plan (about 40-50 Lectures):

Lecture No.	**Topic**

1.	Two and Four probe method for the measurement of resistivity
2.	Resistivity measurement with temperature and magnetic field, Vander Pauw method
3.	Hall measurement- Hall coefficient, mobility, carrier concentration
4.	Heat capacity measurement
5.	Thermal conductivity
6.	Thermoelectric properties
7.	Impedance analyzer (LCR meter), Network analyzer
8.	Dielectric properties measurement with variable temperature and frequency, dielectric loss, Impedance spectroscopy, Cole-Cole, Bode plots, Constant Phase Element (CPE)
9.	Ferroelectric properties measurement- instrumentation, sample preparation, P-E loop measurement with temperature
10.	Fatigue, Pyroelectric and multiferroic properties measurement
11.	Piezoelectric properties measurement, Piezoresponse force microscopy (PFM)
12.	Vibrating sample magnetometry (VSM)
13.	SQUID (superconducting quantum interference device)-VSM
14.	AC and DC susceptibility measurement
15.	Magnetic force Microscopy (MFM)
16.	Magneto optical Kerr effect (MOKE) and its application for the characterization of magnetic materials
17.	MOKE magnetometer & microscopy- instrumentation, data analysis & applications
18.	Thermal analysis techniques- TGA-DTA, and DSC
19.	Vacuum pumps (Rotary and Turbo pump)
20.	Low pressure measurement (Penning and Pirani gauge)
21.	Thin film thickness measurement
22.	Electron probe microanalyzer (EPMA)
23.	Energy dispersive X-ray spectroscopy (EDS) and Wavelength dispersive X-ray spectroscopy (WDS)
24.	Auger electron spectroscopy (AES)
25.	Inductive coupled plasma - Mass spectroscopy (ICP-MS)
26.	Nuclear magnetic resonance (NMR)
27.	Electron spin resonance (ESR)
28.	UV-VIS spectroscopy, and band gap analysis
29.	Fourier transform Infrared spectroscopy (FTIR)
30.	Raman spectroscopy- working principle, instrumentation, application
31.	Surface enhanced Raman spectroscopy (SERS), and Confocal Raman Microscopy
32.	Dynamic light scattering (DLS)
33.	BET analyzer- working principle, instrumentation, sample preparation, Type of isotherm
34.	Surface area, Texture analysis (pore shape, pore size, and pore distribution analysis) using BET
35.	X-ray scattering, working principle ofsmall angle X-Ray scattering (SAXS), instrumentation, data analysis

36.	X-ray absorption and fluorescence, X-ray absorption spectroscopy (XAS), Instrumentation, synchrotron X-ray source
37.	X-ray absorption near edge structure (XANES)
38.	Extended X-ray absorption fine structure (EXAFS)
39.	Basics of electrochemistry, Cyclic voltammetry (CV) and its application
40.	Electrochemical impedance spectroscopy (EIS), analysis of EIS data with different equivalent circuit model, application of EIS

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 2nd**	**Year 2020-21**

Name of Course	**Research Methodology**
Course Code	**NT-524**
Core / Elective / Other	**Core**

Prerequisite:

1.	Aptitude for ethical and quality research

Course Outcomes:

1.	Students will be able to develop understanding on various types of research, objectives of doing research, research process, data analysis, research designs and sampling.

Description of Contents in brief:

1.	Foundation research, problem identification and formulation, concept and importance of research, Qualitative and quantitative research, data generation and interpretation, technical report and paper writing, Ethical issues related to publishing and plagiarism, Bibliography management. Managerial skills, Industry institution visits and interaction.

List of Text Books:

1.	Beri G.C.: Marketing Research (TMH Publishers Ltd, New Delhi)
2.	Chawla D. &Sondhi N: Research Methodology Concepts and Cases (S. Chand & Company Ltd)
3.	Cooper & Schindler Business Research Methods (McGraw-Hill)
4.	Dr. Shajahan S.: Research Methods for Management (JAICO publishing house)

List of Reference Books:

1.	Green, Tull&Albaum: Research for Marketing Decisions (PHI Pvt. Ltd)
2.	Kothari C.R: Research Methodology Methods & Techniques (New Age International Publisher)
3.	Luck D. & Rubin D.: Marketing Research, (PHI Pvt. Ltd)
4.	Wilson J.: Essential of Research Methods, (SAGE Publication)
5.	Sachdeva J.K.: Business Research Methodology, (Himalaya Publishing)

URLs:

1.	https://nptel.ac.in/courses/121/106/121106007/
2.	https://nptel.ac.in/courses/109/106/109106095/
3.	https://nptel.ac.in/courses/110/105/110105091/
4.	https://shodhganga.inflibnet.ac.in/bitstream/10603/71970/14/14_chapter%204.pdf

Lecture Plan (about 40-50 Lectures):

Lecture No.	**Topic**
1.	Introduction: Research
2.	Tools of research
3.	Charts, types, uses
4.	Graphs, types, uses
5.	Sources of data
6.	Data collections methods
7.	Instruments for data collection
8.	Data analysis
9.	What is Research writing

10.	What, why and how of technical and research writing
11.	Literature review
12.	Writing about methods, results, and discussion of results
13.	The writing Process
14.	Research Ethics
15.	Finding what to Read
16.	Elements of Writing
17.	Writing Skills
18.	Literature review: Supporting your claim
19.	Outlining
20.	Methodology: Introduction
21.	Tools for writing up Literature reviews and Methodology
22.	Qualitative research
23.	Quantitative research
24.	Writing the results section
25.	Discussion of results
26.	Technical report writing
27.	Paper writing
28.	Writing the Conclusion section
29.	Bibliography management
30.	Academic Integrity
31.	Intellectual property right (IPR)
32.	Plagiarism
33.	Using and acknowledging sources
34.	Revising
35.	Editing and Proof reading
36.	Choosing a Journal for publication of research findings
37.	Responding to reviewers comments
38.	Wrap up
39.	Choosing Industry and Institutions for visits
40.	Industry and Institutions visits and interaction
41.	Writing the summary of visits

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 2^{nd}**	**Year: 2021-22**
Name of Course	**Nanomaterials Characterization Laboratory**		
Course Code	**NT-525**		
Core / Elective / Other	**Core**		

Prerequisite:	
1.	Probe microscopy, ferroelectricity, Debye Scherrer equation
Course Outcomes:	
Upon successful completion of the course the student will be able to:	
1.	Develop observational skills and make novel findings in day-to-day application
2.	Evaluate dielectric constant, band gap and electric polarization measured by impedance spectroscopy, UV-Vis spectroscopy, and P-E Loop Tracer, respectively
3.	Analyze the morphology and topography of the samples from the obtained data of SEM and AFM, respectively
4.	Implement the knowledge of experimental physics for solving the problems of engineering
Description of Contents in brief:	
1.	Study of Nanomaterials using AFM
2.	Photoluminescence study of Nanomaterials
3.	Determination of internal lattice micro strain and crystallite of a given poly-crystalline material using Debye Scherrer pattern
4.	Study of Nanomaterials using SEM
5.	Study of Nanomaterials using UV-Vis spectroscopy and calculating band gap
6.	To study the parameters affecting the efficiency and fill factors of a solar cell
7.	To study Hysteresis properties of ferroelectric materials using P-E Loop Tracer
8.	Dielectric Measurements using Impedance Spectroscopy
9.	Pore size analysis of nanomaterials using BET
10	Designing LEDs & solar cells based on organic semiconductors, perovskites, and quantum-dots using Setfos Simulation software.
List of Text Books:	
1.	Dielectric Phenomena in Solids by Kwan Chi Kao, (Academic Press)
2.	Elements of X-Ray Diffraction by B.D. Cullity, (Pearson)
3.	Physics of Low Dimensional Systems, J.L. Moran-Lopez, (Springer)
4.	Nanotechnology: An Introduction to Synthesis, Properties and Applications of Nanomaterials, Thomas Varghese & K.M. Balakrishna, (Atlantic)
List of Reference Books:	
1.	Field Emission Scanning Electron Microscopy: New Perspectives for Materials Characterization by Nicolas Brodusch, Hendrix Demers, et al., (Springer)
2.	Atomic Force Microscopy/Scanning Tunneling Microscopy 3, Samuel H. Cohen, Marcia

	L. Lightbody,(Springer)
3.	Purification of Laboratory Chemicals, W.L.F. Armarego (Butterworth-Heinemann)
URLs:	
1.	https://swayam.gov.in/nd1_noc20_mm19/preview
2.	https://nptel.ac.in/courses/115/105/115105121/
3.	https://nptel.ac.in/courses/118/104/118104008/
4.	https://nptel.ac.in/courses/118/102/118102003/
5.	https://nptel.ac.in/courses/118/106/118106021/
6.	https://www.youtube.com/watch?v=VdNhREmkrmE
7.	https://www.youtube.com/watch?v=vYk-jVMTd-U
8.	http://www.infocobuild.com/education/audio-video-courses/chemistry/HeterogeneousCatalysis-IIT-Delhi/lecture-09.html
9.	https://www.youtube.com/watch?v=qXLStQQxHzU
10.	https://nptel.ac.in/courses/113/104/113104090/
11.	https://www.youtube.com/watch?v=mCgXsEyQZSI
12.	https://www.youtube.com/watch?v=z_8aJPLr21E

Lab Plan (about 45 Lectures):

Lecture No.	**Topic**
15x3=45 Periods	15 Labs of 3 periods

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 1st/2nd**	**Year: 2021-22**
Name of Course	**Semiconductor Devices**		
Course Code	**NT-557**		
Core / Elective / Other	**Elective (A)**		
Prerequisite:			
1.	The knowledge of physics basic semiconductor.		
Course Outcomes: At the end of the course, the student will be able to:			
1.	Understand the energy band diagram and working of diodes and transistors.		
2.	Differentiate the working and application of semiconductor PN diodes, zener diode, tunnel diode, photo diode, Schottky barrier diode, SCR.		
3.	Apply the knowledge of semiconductors to illustrate the functioning of basic electronic devices.		
4.	Demonstrate the switching and amplification application of the semiconductor devices.		
5.	Design a simple DC power supply and rectifiers to solve the specific engineering problem.		
Description of Contents in brief:			
1.	**Semiconductor Junction:** Semi conducting materials, p-n junction, space charge and electric field distribution at junctions, forward & reversed biased condition, minority & majority carrier currents		
2.	**Diodes**: Zener and avalanche break downs, Schottky barrier, Shockley diode & silicon control rectifier, Zener diodes, tunnel diodes, photo diodes.		
3.	**Transistor**: Two port network analysis, H, Y & Z parameters, BJT in CE configuration, Constants of CB & CE amplifier, FET, MOSFET, Equivalent circuit of FET. Source amplifier. Idea of transistor biasing and amplifiers.		
List of Text Books:			
1.	Integrated Electronics Analog and digital Circuit: J Millman & C.C. Halkias (Tata McGraw-Hill)		
2.	Physics of Semiconductor Devices: S.M. Sze (John Wiley).		
3.	Semiconductor Physics and Devices: D. Neamen (Tata McGraw-Hill)		
4.	Semiconductor Device Fundamentals: Robert F. Pierret (Addison-Wesley)		
List of Reference Books:			
1.	Solid State Electronics: B. G. Streetman (Prentice Hall India)		
2.	Fundamentals of Electrical and Electronics Engineering: B. L. Theraja (S. Chand)		
3.	Fundamentals of Semiconductors Physics and Materials Properties: P. Yu, M. Cardona (Springer)		
4.	Solid State and Semiconductor Physics: J. P. McKelvey (Krieger Publishing Company)		
5.	Introduction to Solid State Physics: C. Kittel. (John Wiley)		

URLs:	
1.	https://nptel.ac.in/courses/108/108/108108122/
2.	https://nptel.ac.in/courses/108/108/108108112/
3.	https://www.youtube.com/watch?v=Nf8uEiY4Z-k

Lecture Plan (about 40-50 Lectures):

Lecture No.	**Topic**
Lecture 1	Introduction to the syllabus
Lecture 2	Band theory of Solids: Formation of band in solids
Lecture 3	Classification of solids into conductor, semiconductor and insulator
Lecture 4	Properties of Semiconductor, majority and minority carriers, recombination, effect of temperature
Lecture 5	Classification of semiconductor: intrinsic and extrinsic
Lecture 6	Carrier concentration and Fermi level
Lecture 7	P-type Semiconductor
Lecture 8	Energy band diagram and Fermi level of P-type semiconductor
Lecture 9	N-type semiconductor
Lecture 10	Energy band diagram of N-type semiconductor
Lecture 11	Charge Carrier concentration in intrinsic and extrinsic, Temperature dependence of carrier concentration
Lecture 12	Tutorial/case study on semiconductor
Lecture 13	PN Junction: Formation, depletion region, barrier potential
Lecture 14	Space charge and electric field distribution at junction
Lecture 15	PN Junction diode,forward and reverse biased condition
Lecture 16	Reverse saturation current, diode current equation, effect of temperature on diode current
Lecture 17	Minority & majority carrier currents
Lecture 18	Working and current-voltage characteristics of PN Junction diode
Lecture 19	Energy band diagram of PN Junction diode
Lecture 20	Applications of diode like rectifiers, switching, and logic.
Lecture 21	Tutorial/case study on PN junction diode
Lecture 22	Breakdown
Lecture 23	Avalanche and Zener breakdown
Lecture 24	Zener diodes: Principle, symbol
Lecture 25	Working and current-voltage characteristics of Zener diode
Lecture 26	Application of Zener diode: voltage regulator
Lecture 27	Schottky barrier,Schottky barrier height
Lecture 28	Schottky diode: Working and current-voltage characteristics
Lecture 29	Shockley diode: Working and current-voltage characteristics
Lecture 30	Silicon control rectifier: Principle, working and characteristics
Lecture 31	Tutorial/case study on Zener and Shockley diode
Lecture 32	Tunneling effect, Tunnel diodes, working and characteristics of tunnel diode
Lecture 33	Photo emission, photoconduction, photovoltaic effect, Photo diodes
Lecture 34	Two port network analysis
Lecture 35	H,Y & Z parameters
Lecture 36	Bipolar Junction transistor (BJT): Working and input-output characteristics
Lecture 37	Current gain. BJT in common emitter (CE) configuration, common base

	(CB) configuration
Lecture 38	Bias design for BJT's. Bias stabilization using collector and emitter feedback, and voltage dividers.
Lecture 39	BJT amplifiers, AC and DC amplifier gain, input and output impedance, effect of source and load resistance.
Lecture 40	Idea of transistor biasing and amplifiers, load line analysis of transistor amplifiers.
Lecture 41	Field Emission Transistor (FET): P-channel and N-channel, symbols, drain and transfer characteristics, definition of pinch-off voltage
	FET biasing:Fixed bias, self-bias, and voltage divider bias.
Lecture 42	Graphical and algebraic bias solutions, junction FET specifications,
Lecture 43	Comparison of FET over BJT, Equivalent circuit of FET
Lecture 44	Metal Oxide Semiconductor Field Effect Transistor (MOSFET),Enhancement and depletion type MOSFET
Lecture 45	Working and input-output characteristics of MOSFET, MOSFET Biasing
Lecture 46	Source amplifier
Lecture 47	Tutorial/case study on transistors

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 1st/2nd**	**Year: 2021-22**
Name of Course	**Molecular Electronics and Biomolecules**		
Course Code	**NT-560**		
Elective	**Group (A)**		

Prerequisite:	
1.	Basic knowledge of properties of materials, bonding, band gap etc,
2	Basic knowledge of simple and complex molecules, organic materials,
3	Basic knowledge of semiconductor devices, mechanical gears,
Course Outcomes: At the end of the course, the student will be able to:	
1.	Understand the application of naomaterials in the field of biotechnology
2.	Synthesis of organic some semiconductors and understand the role of molecules as switches, biometric components, conducting polymers and light emitting polymers
3.	Detailed knowledge about self-assembly of complex organic molecules and molecular interconnections.
4.	Understand the mechanism of integration of molecular components into functional devices.
5.	Develop an understanding of structural and functional principles of bio machines, interfacing of bio and non bio materials and porous silicon.
Description of Contents in brief:	
1.	Organic semiconductors, Organic molecules as switches, motor-molecules and biomimetic components, conducting polymers, light emitting polymers, The self-assembly of complex organic molecules, Molecular connections and the integration of molecular components into functional devices**,** Contact issues, Structure of biomolecules; Biotechnology, recombinant DNA technology, molecular biology. Structural and functional principles of bio nanomachines, Interfacing bio with non-bio materials, Porous silicon
List of Text Books:	
1.	Molecular Electronics: T. Helgakar (Wiley,VCH)
2.	Semiconductor Quantum Dots: MasumotaTakaga (Springer)
List of Reference Books:	
1.	Nanobiotechnology: Inorganic Nanoparticles vs Organic Nanoparticles- Jesus M. de la Fuente, V. Grazu (Elsevier)
2.	Molecular Electronics: Loan Baldea (Jenny Stanford Publishing)
3.	Biomolecules: N Arumugam (Saras Publication)
URLs:	
1.	https://www.weizmann.ac.il/materials/Cahen/research-activities/bio-molecular-electronics
3.	https://www.ch.ic.ac.uk/local/organic/tutorial/steinke/4yrPolyConduct2003.pdf
4.	https://www.rsc.org/news-events/journals-highlights/2019/apr/molecular-electronics/

Lecture Plan (about 40-50 Lectures):

Lecture No.	**Topic**
1.	Introduction/recall primary and secondary bonding,

2.	functional group, pH and water molecule
3.	Organic molecules and Biomimetics
4.	Molecules that can be used as actuator or photo chromic devices
5.	Single electron transistors
6.	Motor molecules
7.	Molecular machines
8.	Organic semiconductor and comparison with its counterpart
9.	Transport mechanism in solids, semiconductor and polymers
10.	Conjugated-Conducting polymer
11.	Transparent and flexible conducting films
12.	Light emitting polymers (LEPs)
13.	LEDs, Organic Light emitting devices
14.	Display devices LCD and LED
15.	OLED, TOLED, active and passive matrix
16.	Flexible display
17.	Self-assembly of organic molecules
18.	Interconnect of bio and synthetic molecules
19.	Integrating bio and synthetic molecules
20.	Formation of molecular devices
21.	Contact and functional issues
22.	Introduction to biotechnology
23.	Introduction to Nanobiotechnology
24.	Biomimetics: lessons from nature
25.	Molecular biology
26.	macromolecules (or polyanions)
27.	Proteins, carbohydrates, lipids, and nucleic acids
28.	Amino acids, RNA
29.	Introduction to Structure of DNA
30.	Application of DNA
31.	Application of DNA and other ready available biomolecules in Nanodevices
32.	Plant Molecular biology
33.	Photo sensing biological molecules: chromophore and dyes
34.	Use of biological molecules in optical devices
35.	DSSC and natural photo absorber
36.	UV Shielding and Sun-protection
37.	Structural and functional principles of bio nanomachines
38.	Examples of bio nanomachines
39.	Interfacing: Bio and non biomaterials
40.	Introduction to Porous Silicon
41.	Properties and synthesis of Porous Silicon
42.	Application Porous Silicon: heart stent, artificial bone etc

Name of Program	**M. Tech. (Nanotechnology)**	**Semester: 1st/2nd**	**Year: 2021-22**
Name of Course	**Molecular Structures**		
Course Code	**NT-571**		
Core / Elective / Other	**Elective (A)**		

Prerequisite:

1.	Structure of an atom, Pauli's exclusion principle, Bohr's theory

Course Outcomes:

1.	Students will be able to compare between atomic emission spectroscopy and atomic absorption spectroscopy; Atomic emission / absorption spectrophotometer.
2.	Understand the principles of Rotational Spectroscopy and calculate bond lengths and atomic mass from Rotational Spectra of Diatomic molecules.

Description of Contents in brief:

1.	Molecular structure: Born-Oppenheimer approximation; Electronic structure ionic and covalent bonding, H_2, H_2^+; Vibrational and rotational structure. Molecular Spectra: Microwave, infrared and optical spectra of molecules; selection rules, experimental set-ups and examples; Raman spectroscopy. Ortho -Para states. Molecular processes: Collisions with electrons and heavy particles; Experimental techniques.

List of Text Books:

1.	Physics of Molecules: Wolf Gang Demtroder (WILEY-VCH)
2.	Introduction to the Physics of Matter: Basic Atomic, Molecular, and Solid-State Physics: Nicola Manini (Springer)
3.	Hand Book of Physics & Quantum Chemistry: Stephen Wilson, Peter F. Bernath, Roy McWeeny (WILEY-VCH)

List of Reference Books: ,

1.	Introduction to Molecular Spectroscopy: G. M. Barrow, (McGraw Hill)
2.	Molecular Quantum Mechanics: Peter Atkins, Rionald Friedman (Oxford University Press)
3.	The Theory of Atomic Structure and Spectra: Robert D. Cowan (University of California Press)
4.	Springer Handbook of Atomic, Molecular, and Optical Physics: Gordon W. F. Drake, (Springer)

URLs:

1.	https://nptel.ac.in/courses/115101003/
2.	https://nptel.ac.in/courses/115101012/
3.	https://nptel.ac.in/courses/104/106/104106122/
4.	https://nptel.ac.in/courses/103108124/
5.	https://chem.libretexts.org/Courses/Howard_University/General_Chemistry%3A_An_Atoms_First_Approach/Unit_1%3A__Atomic_Structure/Chapter_2%3A_Atomic_Structure/Chapter_2.3%3A_Atomic_Spectra_and_Models_of_the_Atom
6	https://www.sciencedirect.com/topics/physics-and-astronomy/atomic-spectra

Lecture Plan (about 40-50 Lectures):

Lecture No.	Topic
1.	Basic principles of spectroscopy
2.	Theories explaining the structure of atoms and the origin of the observed spectra
3.	Quantum mechanics of hydrogen atom and many electron atom
4.	Atom in electric magnetic fields
5.	Different models for atomic structures, atomic effect such as space quantization and Zeeman effect
6.	Stark effect, Paschen Back effect
7.	Lande g-factor, Spectral consequences of applied fields
8.	Bonding: Vander Waals, covalence, Ionic, metallic
9.	The molecular bonding and molecular energies
10.	Hydrogen atom review
11.	Degeneracy, Spin-orbit coupling and fine structure
12.	Hyperfine interactions
13.	Helium energy levels
14.	Spectral consequences of fine structure
15.	Molecular spectroscopy
16.	Quantum mechanical description of a molecular system
17.	Born-Oppenheimer approximation
18.	Approximation methods for the calculation of molecular wave-functions
19.	The variation method and its applications
20.	Molecular Orbital (MO) approximation
21.	Molecular states and molecular energy
22.	Molecular symmetry and Group theory, Molecular rotation, Numerical Problems
23.	Selection rules
24.	Experimental probes Raman and infrared spectroscopy
25.	The rotational selection rules
26.	Rotational spectra
27.	The vibration of molecules
28.	Molecule as a rigid rotator
29.	Rotaional-Vibrational spectra
30.	The molecule as harmonic oscillator
31.	Molecule as anharmonic oscillator
32.	The molecule as non-rigid rotator
33.	The Raman Spectra
34.	Electronic Spectra: Franck Condon Principle
35.	Isotope effect on Electronic Spectra
36.	Fluorescence and phosphorescence, optical spectra of molecules
37.	Classifications of Molecular Electronic states
38.	Spectra of Alkali Elements
39.	Continuous and Diffuse Molecular spectra
40.	Ortho-Para states
41.	Molecular processes: Collisions with electrons and heavy particles
42.	Electron- electron interactions
43.	Spin-orbit coupling and fine structure

Name of Program	M.Tech. (Nanotechnology)	Semester: 1st/2nd	Year: 2021-22

Name of Course	**Advanced Topics in Physics**
Course Code	**NT-573**
Core / Elective / Other	**Elective (A)**

Prerequisite:

1.	Fundamental Physics knowledge

Course Outcomes:

1.	Students will be able to understand about Electrets, Luminescence and preparation techniques and applications of amorphous semiconductors

Description of Contents in brief:

1.	Electrets physics: various types of electrets, methods of preparation, various studies on electrets, uses of electrets. Luminescence: various kinds of luminescence, theory of luminescence, paramagnetic behavior, activators and co-activators, Clustering, color centers. Preparation techniques and application. Amorphous semiconductor materials. Preparation techniques in bulk form & in thin form. Rocking and quenching of materials. Characterization of amorphous materials.

List of Text Books:

1.	Amorphous Materials: S.R. Elliot (Longman)
2.	Physics of Amorphous Solids: Richard Zallen(Wiley-VCH)
3.	The Physics and Applications of Amorphous Semiconductors:Arun Madan , M. P. Shaw (Academic Press)

List of Reference Books:

1.	Physics of Magnetic Nanostructures:Frank J. Owens (Wiley-VCH)
2.	Electrets In Engineering:Vladimir N. Kestelman, Leonid S. Pinchuk, Victor A. Goldade (Springer)

URLs:

1.	https://nptel.ac.in/courses/122/106/122106027/
2.	https://nptel.ac.in/courses/104/104/104104084/
3.	https://nptel.ac.in/courses/104/104/104104084/
4.	https://www.sciencedirect.com/topics/neuroscience/luminescence
5.	https://link.springer.com/chapter/10.1007/978-3-319-48933-9_24

Lecture Plan (about 40-50 Lectures):

Lecture No.	Topic
1.	Introduction to Electrets
2.	Charges Materials Electrets classes
3.	Electrets Material: Fluoropolymers
4.	Energy diagram and density of states for a polymer
5.	Electrets Materials: Polyethylene (HDPE, LDPE, XLPE)
6.	Cellular and porous polymers

7.	Fields of an electrets
8.	Force of an electrets on an electrode
9.	Currents in an electret
10.	Charge transport equations
11.	Various types of electrets
12.	Methods of preparation of electrets
13.	Uses of electrets
14.	Luminescence: Introduction
15.	Various kinds of luminescence
16.	Theory of luminescence
17.	Introduction to Diamagnetism and Paramagnetism
18.	Paramagnetic behavior
19.	Theory of Para magnetism
20.	Activators and co-activators
21.	Properties of activators and co-activators
22.	Clustering
23.	Color centers
24.	Preparation techniques and applications
25.	Fundamental concepts of semiconductors
26.	Amorphous semiconductor
27.	Classification of amorphous Semiconductors
28.	Atomic Structure of amorphous Semiconductors
29.	Amorphous semiconductor materials
30.	Mobility in semiconductor materials
31.	Structural properties of amorphous semiconductors
32.	Optical and properties of amorphous semiconductors
33.	Electrical properties of amorphous semiconductors
34.	Electronic State
35.	Structural properties of amorphous semiconductors
36.	Optical absorption and luminescence
37.	Energy Band Structure of Amorphous Semiconductors
38.	Defects in Amorphous semiconductors
39.	Preparation techniques in bulk form & in thin form.
40.	Rocking and quenching of materials. Characterization of amorphous materials

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