DEPARTMENT OF NANOTECHNOLOGY

NORTHEASTERN HILL UNIVERSITY, SHILLONG

REVISED SYLLABUS

MASTER OF TECHNOLOGY (M.Tech.) IN NANOTECHNOLOGY

2023

Course Structure & Syllabus

For

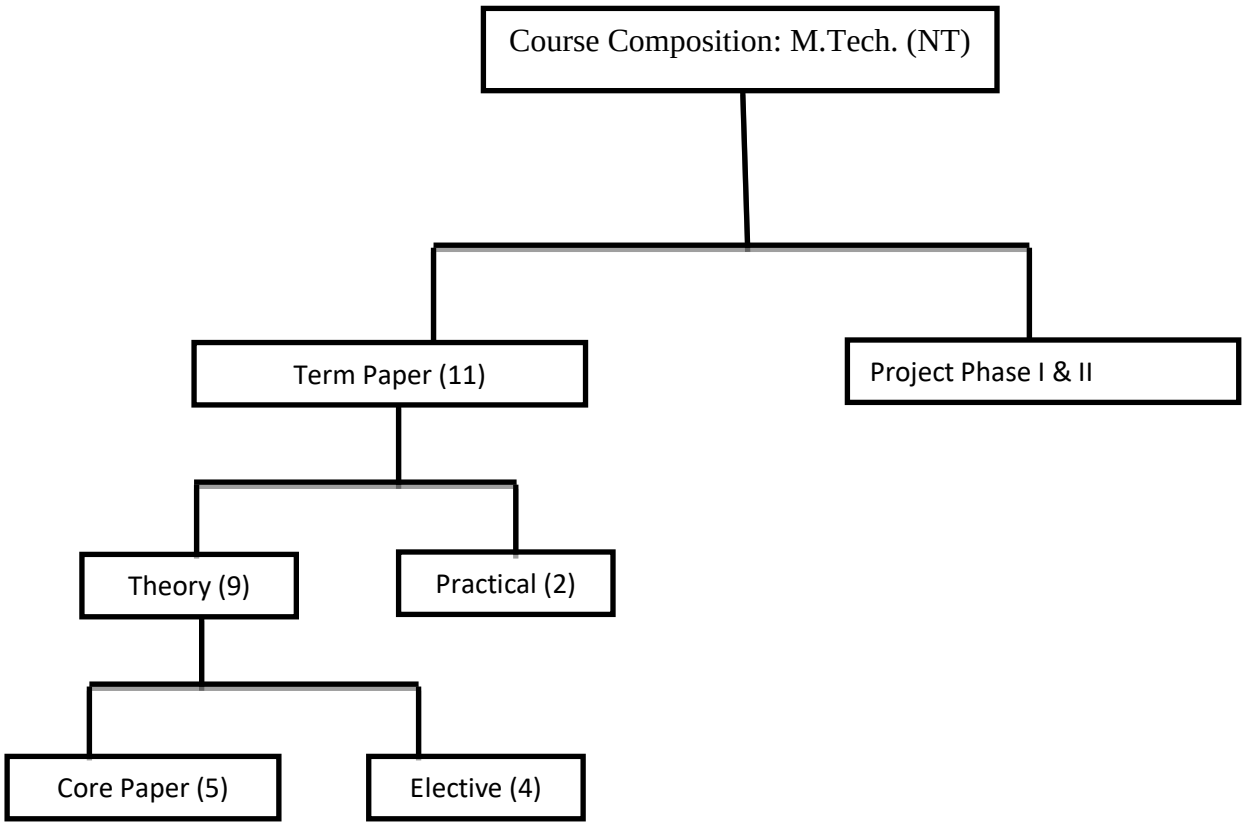
REVISED M.Tech. (NT) Program

Table of Contents

Objectives

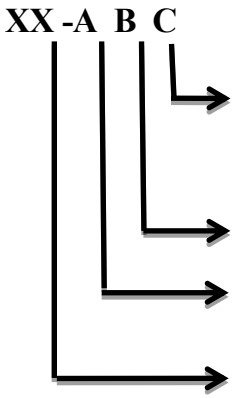
This two years M.Tech. (NT) program aims to prepare candidates for research development as well as for future prospects of nanoscienceandnanotechnology. To provide the students stateofart knowledge of recent technologies and to develop their capacity to tackle unknown engineering problems, the syllabus has balanced the core, specialized and elective subjects, integrating the practical and field exercises with challenging research oriented project activities.

Course Layout



Adopted Course Code

1. Subject coding for Core papers



Subject number (however for the elective papers it is designated as XX-01,02,03 etc)

Paper designation (CC- Core Course, DSEC-Discipline specific Elective Course, etc.)

Paper code Yearly code (First Year-5, Second Year-6)

Department code

COURSE STRUCTURE

TEACHING PROGRAMME FOR

M.TECH NANOTECHNOLOGY

Year: I **Semester: I**

Sl. NO	Paper Code	Paper Name	Periods			EVALUATION SCHEME				Total	Credits
						Internal			ESE		
THEORY			L	T	P	TA	CT	TOT			
1	NT-CC-500	Nanotechnology and Quantum Mechanics of Nanostructured systems	4	0	0	10	15	25	75	100	4
2	NT-CC-501	Nanomaterial Laboratory I	1	0	7	10	15	25	75	100	4
3	NT-DSEC-502XX	Discipline Specific Elective Course (DSEC)-I	3	0	1	10	15	25	75	100	4
4	NT-DSEC-503XX	Discipline Specific Elective Course (DSEC)-II	3	0	1	10	15	25	75	100	4
5	NT-GEC-504	Data Analysis of sophisticated instruments (Crystallography, microscopy and spectroscopy)	4	0	0	10	15	25	75	100	4
									Total	500	20

TA - Assessment by Teacher **CT** - Class Test **ESE** - End Semester Examination

L - Lecture **T** – Tutorial **P** – Practical

Contact Hours:300hrs Total Marks: 500 Total Credits: 20

Discipline Specific Elective Course-I

1. NT-DSEC-50201:Nanobiotechnology
2. NT-DSEC-50202: Lithography and Nanofabrication

Discipline Specific Elective Course (DSEC)-II

1. NT-DSEC-50302: Advanced Nanostructured Materials
2. NT-DSEC-50303:. Nanophotonics.

Year: I **Semester: II**

Sl.No.	Paper Code	Paper Name	P/W			EVALUATION SCHEME				Total	Credits
			L	T	P	Internal			ESE		
THEORY						TA	CT	TOT			
1	NT-CC-505	Mathematical Methods & Simulation for Engineers	4	0	0	10	15	25	75	100	4
2	NT-CC-506	Nanomaterial Laboratory II	1	0	7	10	15	25	75	100	4
3	NT-DSEC-507XX	Discipline Specific Elective Course (DSEC)-I	3	1	0	10	15	25	75	100	4
4	NT-DSEC-508XX	Discipline Specific Elective Course (DSEC)-II	3	1	0	10	15	25	75	100	4
5	NT-RM-509	Research Methodology & Proposal Writing	4	0	0	10	15	25	75	100	4
6	NT-SEC-510	Skill Enhancement Course (SEC) [MOOCS - I/Department course]	4	0	0	10	15	25	75	100	4
									Total	600	24

TA- Assessment by Teacher **CT**-Class Test **ESE** -End Semester Examination

L -Lecture **T** – Tutorial **P** – Practical

Contact Hours: 360hrs Total Marks: 600 Total Credits: 24

Discipline Specific Elective Course-I

NT-DSEC-50701	Carbon Nanostructures and Applications
NT-DSEC-50702	Polymer and Nanocomposites
NT-DSEC-50703	Optical Properties of nanostructure system

Discipline Specific Elective Course (DSEC)-II

NT-DSEC-50801	Electronics and Magnetic properties of Nanostructures
NT-DSEC-50802	Nanotechnology for Energy Devices

Skill Enhancement Course:

Department Course Courses from MOOCS- Related to Skill Development

1. NT-SEC-5101: Fabrication of Nanomaterials
2. NT-SEC-5101: Thin Film Technology

Year: II **Semester: III**

Sl.No.	Paper Code	Paper Name	P/W			EVALUATION SCHEME			Total	Credits
			L	T	P	Internal		ESE		
THEORY/PROJECT						TA	TOT			
1	NT-CC-600	Semiconductor and Nanodevices	3	1	0	10	25	75	100	4
1	NT-DSEC-602	Project Phase I*	0	0	30	125	125	375	500	20
		Total	0	0	30	150	150	450	600	24

*****Evaluation of Project Phase -I shall be a continuous assessment process comprising:

Dissertation(DSEC), Problem Identification and Review of Related Literature, Proposal writing and Presentation, Data Collection, Data analysis, Interpretation and discussion, Report Writing

TA- Assessment by Teacher **CT**-Class Test **ESE-**End Semester Examination

L - Lecture **T** – Tutorial **P** – Practical

Contact Hours: 3000 Total Marks: 600 Total Credits: 24

Sl.No.	Paper Code	Paper Name	P/W			EVALUATION SCHEME			Total	Credits
			L	T	P	Internal		ESE		
THEORY/PROJECT						TA	TOT			
1	NT-DSEC-606	Project Phase II*	0	0	30	125	125	375	500	20
		Total	0	0	30	125	125	375	500	20

*****Evaluation of Project Phase -II shall be a continuous assessment process comprising:

Dissertation(DSEC), Problem Identification and Review of Related Literature, Proposal writing and Presentation, Data Collection, Data analysis, Interpretation and discussion, Report Writing

TA- Assessment by Teacher **CT**-Class Test **ESE-**End Semester Examination

L - Lecture **T** – Tutorial **P** – Practical

Contact Hours: 300 Total Marks: 600 Total Credits: 20

***Total Credit for M.Tech. in Nanotechnology is **88** credits.*

Detailed Syllabus

Year I Semester I

NT-CC-500 Nanotechnology and Quantum Mechanics of Nanostructured systems **Credit: 4**

Subject Code: *NT-CC-500*
Subject Name: Nanotechnology and Quantum Mechanics of Nanostructured systems
No. of Hours Per Week: *Lectures-4.*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75*
Duration of End Semester Examination: *Three Hours.*

Unit I: Introduction of Nanomaterials: Introduction to Nanoscience and Nanotechnology, Assembling and self-organization of nanostructures, Nanotube, graphene, nanoclusters and nanowire, Importance of size distribution, size measurement, physical and chemical techniques on preparation of nanoparticles

Unit II: Instrumentation in Nanotechnology: X-Ray Diffraction, Electron Microscopy-TEM, SEM, Scanning electron microscopy, Atomic Force Microscopy and spectroscopy.

Unit III: Quantum Mechanics: Uncertainty principal in 1D wavepacket and applications of uncertainty principle, Schroedinger's equations and their applications in one dimension- infinite deep potential, Potential step and square well potential.

Unit IV: Quantization in nanostructures: Density of states, low dimensional structures, number of states and density of states in nanostructures, one dimensional superlattice of quantum dots.

Textbooks:

1. C. Julian Chen, Introduction to Scanning Tunnelling Microscopy Monographs on the Physics and Chemistry of Materials, Springer 2015.
2. D.J. O'Connor, Surface Analysis Methods in Materials Science, Springer, 2008.
3. Ray F. Egerton, Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AFM, Springer, 3rd ed. 2018.
4. G. Cao, Nanostructures &Nanomaterials: Synthesis, Properties &Applications, Imperial College Press, 2014.
5. A.I. Gusev, A.A. Rempel, Nanoecrystalline Materials, Cambridge International Sc. Pub., 2022.
6. G. Aruldhas, Quantum Mechanics, Prentice Hall of India, 2013.
7. R.L. Liboff, Introductory Quantum Mechanics, Pearson Education, 2006.
8. AGhatak and S. Lokanathan, Quantum Mechanics: Theory and Application, 4th Ed, Macmillan, 2004.

References:

1. Robert W. Cahn, Concise Encyclopaedia of Materials Characterization, Second Edition, Elsevier Publication, 2004.
2. Joachim Frank, ThreeDimensional Electron Microscopy of Macromolecular Assemblies: Visualization of Biological Molecules in Their Native State, Kindle 2006.
3. Adam J. Schwartz, Mukul Kumar, Brent L. Adams, and David P, Field Electron Backscatter Diffraction in Materials Science, 2009.

NT-CC-501 NANOMATERIAL LABORATORY I **Credit: 4**

Subject Code: *NT-CC-501*
Subject Name: *Nanomaterials Laboratory I*
No. of Hours Per Week: *Practicals – 15hrs/week*
Marks Distribution: *Sessional Works = 25, End Semester Examination = 75.*
Minimum number of Practicals to be carried out: *Four.*
Question to be answered: *One experiment will be allotted to a student on lottery basis.*
Duration of End Semester Examination: *Three Hours.*

1. To synthesize nanoparticles by ball milling (Top down process) and determination particle size by XRD.
2. Preparation of ZnO nanoparticles with combustion and determination its particle size XRD (Crystalline phase determination, calculation of miller, Unit cell determination.)
3. To synthesize nanoparticles and study of surface topography by using STM/AFM.
4. To analyze the surface topography of semiconductor thin film using AFM and determine thickness across a step.
5 To synthesize thin films by spin coater and confirmation by XRD.
6. To analyze thin films using Raman, FTIR and UV-Visible Spectroscopy.
7. To analyze and characterize the thin films prepared by spin coater by AFM and TEM.
8. To synthesize nanocrystalline lanthanides and study of the Raman and absorption spectra.
9. To determine band gap of semiconductor nanoparticles with optical method and compare with theoretically calculated value.
10. To perform surfactant assisted synthesis of ZnO nanoparticles and their characterizations.
11 To plot the given data of XRD, UV, FTIR and PL for analysis.

Text Books:

1. C. Julian Chen, Introduction to Scanning Tunnelling Microscopy Monographs on the Physics and Chemistry of Materials, Springer, 2009.
2. D.J. O'Connor, Surface Analysis Methods in Materials Science, Springer, 2008.

NT-DSEC-50201 NANOBIOTECHNOLOGY **Credit: 4**

Subject Code: **NT-DSEC-5021**
Subject Name: *Nanobiotechnology*
No. of Hours Per Week: *Lectures –3*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination =75.*
Duration of End Semester Examination: *Three Hours.*

Unit I: Cell Biology: Structure and function, DNA and RNA, modern concept of gene, mutation and mutagenesis. DNA double helix, genome structure and organization in prokaryotes and eukaryotes, Central dogma DNA is a genetic material , Experiments, DNA replication ,Mechanism of replication, different types in prokaryotes and eukaryotes.

Unit II: Nanoparticles in drug delivery: Synthesis and characterization of nanoparticles for drug delivery (including solid lipid nanoparticles, synthetic and biopolymeric nanoparticles) and imaging, carbon nanotubes in drug delivery.

Unit III: Nanotechnology in Cancer therapies: Chemotherapy, hyperthermia, photodynamic therapy and toxicity and bioevaluation nanoparticles, LbL self-assembly, Colloids and colloid Assemblies for Bionanotechnology.

Unit IV: Biosensors: Fibre Optic Nanosensors in medical care, Semiconductor and Metal Nanoparticles, Synthesis and Applications, Nanotechnology in Tissue Engineering.Fabrication of biosensors , techniques used for micro-fabrication,micro-fabrication of electrodes-on-chip analysis.

Textbooks:

1. B.Lewin, Genes IX, International Edition. Sudbury: Jones & Bartlett, 2007.
2. Watson James, T. Baker, S. Bell, A. Gann, M.Levine, and R. Losick, Molecular Biology of the Gene, 5th ed., San Francisco: Addison, Wesley, 2000.
3. Alberts, Bruce, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts and Peter Walter. Molecular Biology of the Cell. 4th ed., New York: Garland Science, 2002.

References:

1. Branden, Carl, Ivar, and John Tooze, Introduction to Protein Structure, 2nd Ed. New York: Garland Pub., 1991.
2. Creighton, E. Thomas, Proteins: Structures and Molecular Properties, 2nd Ed. New York: W.H. Freeman, 1992.
3. R. Cantor, P.R.Samuel, Biophysical Chemistry, W.H., Freeman & Co., 1985.

NT-DSEC-50202 LITHOGRAPHY AND NANOFABRICATION **Credit: 4**

Subject Code: **DSEC-50202**
Subject Name: *Lithography and Nanofabrication*
No. of Hours Per Week: *Lectures - 4.*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75.*
Duration of End Semester Examination: *Three Hours.*

Unit I: Optical lithography: Optical lithography, Photomask, Binary mask, Phase shift mask, Holographic lithography, Ion projection lithography,Maskless optical projection lithography, Zone plate array lithography, Extreme ultraviolet lithography.

Unit II: High Resolution Lithography: Scanning electron beam lithography, Maskless EBL, Parallel and direct write beam systems, X-ray lithography,Ion beam lithography, Focused ion beam lithography,andMasked ion beam lithography.

Unit III: Nanoimprint and soft lithography: Nanoimprint lithography (NIL), UV,NIL, Soft Lithography, Moulding/Replica moulding, Edge lithography, Dip-Pen Lithography, Etching techniques, Ion beam etching (IBE).

Unit IV: Semiconductor Lithography: Basic IC Fabrication, Pattterning, Etching, Ion Implantation, Process Integration, Lithography Process, Substrate preparation,Photoresist coating, Post Apply Bake, post exposure bake, pattern transfer, strip.

Textbooks:

1. Harry J. Levinson, Principles of Lithography, SPIE, 2010.
2. David G. Bucknall, Nanolithography and Patterning Techniques in Microelectonics, CRC, 2015.
3. U. Okoroanyanwu,ChemistryLithography,Wiley SPIE, Press USA, 2015.

References:

1. H. Schift et al., Fabrication of polymer photonic crystals using Nanoimprint lithography, Nanotechnology, 16, 261, 2005.
2. M. Baker et al., Lithographic pattern formation via metastable state rare gas atomic beams, Nanotechnology, 15, 1356, 2004.

NT-DSEC-50301 NANOPHOTONICS Credit: 4

Subject Code: NT-DSEC-50301
Subject Name: *Nanophotonics*
No. of Hours Per Week: *Lectures - 4.*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75*
Duration of End Semester Examination: *Three Hours.*

Unit I: Foundations for Nanophotonics: Photons and electrons: similarities and differences, Confinement of photons and electrons, Propagation through a classically forbidden zone, Tunnelling, Localization under a periodic potential, Photonic band gaps, Nanoscale optical interactions, axial and lateral nanoscopic localization.

Unit II: Photonic Crystals: Basic concepts, Photonic Crystals, wave propagation, photonic band gap, light guiding, theoretical Modelling of Photonic Crystals, Methods of fabrication, Nonlinear Photonic Crystals, Applications of Photonic crystals.

Unit III: Nanophotonic Devices: Resonant cavity quantum well lasers and light emitting diodes, Fundamentals of Cavity QED, strong and weak coupling regime, Purcell factor, Spontaneous emission control, Application of microcavities including low threshold lasers, resonant cavity LED.

Unit IV: Nanophototnic for Biotechnology: Near field bioimaging, nanoparticles for optical diagnostics and targeted therapy, Semiconductor quantum dot for bioimaging, up-converting nanophosphors for bioimaging, biosensing, nanoclinics for optical diagnostics and targeted therapy, nanoclinic gene therapy.

Textbooks:

1. John D Joannopoulos, Photonic Crystals, Princeton University Press, ISBN0691037442, 2009.
2. Jean Michel Lourtioz, Photonic Crystals: Towards Nanoscale Photonic Devices, Springer, ISBN 54024431X, 2008.
3. V.M. Shalaev and S.Kawata, Nanophotonics with Surface Plasmons (Advances in Nanooptics and Nanophotonics), 2007.
4. M. ohtsu, K. Kobayashiu, T. Kawazoe, T. Yatsui, M. Naruse, Principles of Nanophotonics, CRC Press, Taylors and Francis Group, 2016.

References:

1. Fredric Zolla, Fundamentals of Photonic Crystal Fibers, Imperial College Press, ISBN 1860945074, 2006.
2. B.E.A. Saleh and A.C.Teich, Fundamentals of Photonics, John Wiley& Sons, New York, 1993.
3. M.Ohtsu, K. Kobayashi, T. Kawazoe, and T. Yatsui, Principles of Nanophotonics(Optics and Optoelectronics), University of Tokyo, Japan, 2003.
4. John D Joannopoulos, R.D. Meade and J. N. Winn, Photonic Crystals: Modelling Flow of Light, Princeton University Press, 1995.

NT-GEC-50302 ADVANCEDNANOSTRUCTURED MATERIALS **Credit: 4**

Subject Code: **NT-GEC-50302**
Subject Name:*AdvancedNanostructured Materials*
No. of Hours Per Week: *Lectures - 4.*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75*
Duration of End Semester Examination: *Three Hours.*

Unit I: Nanoporus materials: Zeolites, Mesoporusmterials, Nanomembranes: Carbon Nanotubes and Graphene, Core-shell and hybrid nanocomposites, Buckyballs. Piezoelectric materials, Electrostatic and Magnetostatic materials.

Unit II: Composite Materials : Non-Polymer Nanocomposites- Metal-Metal, Metal-Ceramic, Ceramic-Ceramic, Carbon Nanotube-Based Nanocomposite, Noble Metal Based Nanocomposites, Preparations And Applications.

Unit III: Applications of nanomaterials: Nano painting, Nano coating, Nanomaterials for Renewable Energy, Quantum wire and dots for advance lasers, LEDs and solar cells, Biological Applications, Mechanical Applications, Optical Applications,.

Unit IV: Interface effects: Laser Annealing, Photodarkening, Photodegradation, Concept Of Interface Effects On The Properties Of Copper Halide Nanocrystals, Persistent Spectral Hole Burning, Photochemical Hole Burning And Its Difference With Quantum Dot Ensembles.

Textbooks:

1. G. Cao, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press, 2016.
2. S. Yang and P. Shen: “Physics and Chemistry of Nanostructured Materials”, Taylor&Francis, 2000.
3. Y.Y.Yu, Advanced NanostruredMaterials: Technology Based, Taylor&Francis, 2018.

References:

1. M. Reza Mozafari Nanomaterials and Nanosystems , Springer(2007).
2. A. S. Edelstein and R. C. Cammarata, “Nanomaterials: Synthesis, Properties and Applications”, Institute of Physics Pub., 1998.

NT-GEC-504 Data Analysis of sophisticated instruments (Crystallography, microscopy and spectroscopy) **Credit: 4**

Subject Code: NT-GEC-504
Subject Name: Handling and data analysis of sophisticated instruments
No. of Hours Per Week: *Lectures – 4*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75.*
Duration of End Semester Examination: *Three Hours.*

Outcome/Knowledge/Skill:This will provide knowledge on the effect of nanomaterials on various environmental factors. This deals with the environment remediation through nanotechnology, nanotoxicology and different methods to analyze the effect of nanotechnology on the environment.

Unit I: Xray Diffraction:nature of X-rays, absorption of x-rays by matter-x-ray fluorescence, x-ray diffraction(Debye-Scherrer Method), reciprocal lattice and diffraction, determination of unit cell.

Unit II: compositional analysis of materials: Classical Wet Analysis, Electro Chemical Methods Analysis, Methods based on molecular absorption, X-ray fluorescence methods, spectroscopic techniques.

UNIT III: Mechanical properties and Mechanical Integrity:
Tension Test, Compression test and bend test, hardness test, fracture tests and basic fatigue test.

UNIT IV: Optical Microscopy: Preparation of specimens, examination of microstructures, magnification, resolution and depth focus, estimation of Grain size.

Textbooks:

1. Cullity, B.D.Elementsof X-rays Diffraction, 4th Edition, AddisionWeley, 2004.
2. Smallman R.E., Modern Physical Mettallurgy and Materials and /engineering, Butterworths, London(1999).
3. Yuchi Ikuhara, JEOL News vil40 (2005) pp21

NT-CC-505 MATHEMATICLA METHODS & SIMULATION FOR ENGINEERS Credit: 4

Subject Code: **NT-CC-505**
Subject Name: *Mathematical Methods & Simulation For Engineers*
No. of Hours Per Week: *Lectures –3, Tutorial 1*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75*
Duration of End Semester Examination: *Three Hours.*

Unit I: Roots of Non-linear and Linear equations: Bisection Method, the Method of False position, Iteration method, Newton Raphson method, Gauss Elimination Method, Jacobi iterative method, Gauss Seidel Method, Convergence of iterative method

Unit II: Numerical Solution of Ordinary Differential Equation: Solution by Taylor's series, Picard's method of successive approximation, Eulers method, Runge Kutta Method, Predictor –Corrector methods, Adams Moulton Method.

Unit III: Least Square Method (Curve fitting): Linear, Non-linear, Polynomial of nth degree, Parabola, exponential function, curvilinear curve fitting, Multi-linear regression.

Unit IV: Numerical differentiation and integration: Derivation using Newtons forward and backward difference formula, Derivatives using Central Difference formula, maxima and minima of tabulated function, numerical integration, trapezoidal rule, simpson's 1/3rule, simpson's 3/8 rule.

Textbooks:

1. Z. Xiao Guo (Ed), Multiscale, Materials Modelling: Fundamental and Applications, Woodhead Publishing Limited, Cambridge, 2017.
2. Erwin Kreyzig, Advanced Engineering Mathematics, John Wiley & Sons, 2004.
3. R.J. Schilling and S.L. Harris, Applied Numerical Methods for Engineers using MATLAB and C, Thomson publishers, New Delhi, 2004.

References:

1. J.H. Rice, Numerical Methods, Software and Analysis, McGraw,Hill, 1983.
2. D. Frenkel and B. Smith, Understanding molecular simulation from algorithm to Applications, Kluwar Academic Press, 1999.
3. Zoe H. Barber, Introduction of Materials Modelling, Maney Publishing, 2005
4. S.C. Chapra and R.P.Canale, Numerical methods for Engineers, Tata McGraw Hill, New Delhi, 2002.
5. P.Nathan, Ida and J.P.A. Bastos, Electromagnetics and Calculation of Fields, Springer, Verlag, 1992.

NT-CC-506NANOMATERIAL LABORATORY II **Credit: 4**

Subject Code: **NT-CC-506**
Subject Name: *Nanomaterial Laboratory II*
No. of Hours Per Week: *Lectures-4.*
Marks Distribution: *Sessional Works =25, End Semester Examination = 75.*
Duration of End Semester Examination: *Three Hours.*

1. To determine the relation of electron concentration versus temperature using MATLAB/suitable software.
2. To determine electron (μn) and hole (μp) mobilities versus doping concentration in Semiconductor using MATLAB/suitable software.
3. To determine Fermi function for different temperatures using MATLAB/ suitable software.
4. Numerical solution of the one Dimensional Schrodinger wave equation of Time independent system using MATLAB/ suitable software program.
5. To study the cyclic voltametric characteristics of Pt-electrode.
6. To study differential pulse voltammetry of Pt-electrode.
7. To study conduction behaviour of Pt-electrode and analysis the curve.
8. Determination of Dielectric properties of nanoparticles and determination of Q-factor.
9. To evaluate the current flowing through a self assemble nanoparticle by LCR meter (AC/DC mode).
10. Determination of diffusion coefficient of KCl dispersed nanoclusters.
11. Calculation of sensitivity of the given nanocluster electrochemical for biosensor.

Text Books:

1. Sarhan M. Musa, "Computational Nanotechnology: Modeling and Applications with MATLAB", CRC Press, 2011.
2. John O. Attia, "Electronics and Circuit Analysis using Matlab", CRC Press, 2001.

References:

1. Simon Li and Yue Fu, "3D TCAD Simulation for Semiconductor Processes, Devices and Optoelectronics", Springer, 2012.
2. Luigi Capodieci, "Optimization Techniques for VLSI Process Modeling and TCAD in Semiconductor Manufacturing", University of Wisconsin--Madison, 1997.

NT-DSEC-50701 CARBON NANOSTRUCTURES AND APPLICATIONS Credit: 4

Subject Code: **NT-DSEC-50701**
Subject Name: *Carbon Nanostructures and Applications*
No. of Hours Per Week: *Lectures – 4*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75.*
Duration of End Semester Examination: *Three Hours.*

Unit I: Carbon Nanomaterials: Types of Graphitic materials, structures, non-planar graphitic materials- Whiskers, Cones and Polyhedral crystals, preparations and applications, electronic properties, synthesis and applications of GPCs (Graphitic Polyhedral Crystals).

Unit II: Synthesis of Carbon Nanotubes: History, types of CNTs, Structure of CNT, CNT synthesis methods: CVD method, laser ablation and electric arc processes, growth mechanisms, purification, comparison of CNT and fullerenes.

Unit III: Application of CNT: Electric and transport properties of SWCNT, novel optical properties, magnetic properties SWCNT, sensors including biosensor.

Unit IV: Graphene: Types and structure of Graphene, Synthesis and functionalization of Graphene, modern applications of graphene, graphene in renewable energy systems, Structure and applications of Graphene Oxide.

Textbooks:

1. Charles P Poole & Frank J. Ownes, Intoduction to Nanotechnology, Wiley, 2013
2. Physical properties of Carbon Nanotube, R Satio, Imperial College Press, 2016.
3. S. Subramony& S.V. Rotkins, Applied Physics Of Carbon Nanotubes : Fundamentals Of Theory, Optics And Transport Devices -2015.

References:

1. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell, 2011.
2. Nanotubes and Nanowires, CNR Rao and AGovindaraj RSC Publishing, 2005.

NT-DSEC-50702POLYMER AND NANOCOMPOSITES **Credit: 4**

Subject Code: **NT-DSEC-50702**
Subject Name: *Polymer and Nanocomposites*
No. of Hours Per Week: *Lectures - 4.*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75.*
Duration of End Semester Examination: *Three Hours.*

Unit I: Polymers: Classification, Polymerizations, and Copolymerization, Properties of polymers, Polymerization Techniques: Bulk, Solution, Suspension and Emulsion polymerizations.

Unit II: Conducting Polymers: Structural characteristics and doping concept, Charge carriers and conducting mechanism, Classification, synthesis and applications of conducting polymers.

Unit III: Polymer Nanocomposites: Definition of nanocomposites, Nanofillers, Classification of nanofillers, Synthesis and properties of nanofillers, Types of nanocomposites, Synthesis of nanocomposites, Polymer/CNMs and Polymer/Nanoclay based composites and their properties and functional applications.

Unit IV: Nanocomposites: Metal nanocomposites, Core-shell structured nanocomposites, Metal with nanoceramic fillers and their mechanical, corrosion resistance properties and functional applications, optical properties of nanocomposites.

Textbooks:

1. Takashi Kato, Liquid Crystalline Functional Assemblies and Their Supramolecular Structures and Bonding, Springer, 2008.
2. Nanostructured Conductive Polymers, Editor. Ali Eftekhari, Wiley 3e, 2018.
3. K. Holmberg, B. Johnson, B. Kronberg, B. Lindman, Surfactants and Polymers in Aqueous Solution, Wiley, 2004.
4. John D. Wright, Nico A.J.M. Sommerdijk, SolGel Materials: Chemistry and Applications, CRC, 2000.

References:

1. George Odian, Principles of Polymerization, 4th edition Wiley, 2004.
2. Lyklema J, Fundamentals of Interface and Colloid Science, Vol.4, Academic press, 2005.

NT-DSEC-50703 OPTICAL PROPERTIES OF NANOSTRUCTURE SYSTEM Credit: 4

Subject Code: **NT-DSEC-50703**
Subject Name: *Optical Properties of Nanostructure systems*
No. of Hours Per Week: *Lectures-4.*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75.*
Duration of End Semester Examination: *Three Hours.*

Unit I: Photoconductivity, Optical absorption & transmission, Photoluminescence, Fluorescence, Phosphorescence,Electroluminescence.

UNIT II: Optical luminescence and fluorescence from direct, bandgap semiconductor nanoparticles, surface-trap passivation in core-shell nanoparticles. Luminescence properties of oxide phosphors.

UNIT III: Influence of Host Lattice, Study Energy Level diagram of the metal and lanthanide ions. Radiative Return to the ground state: Emission, Non-radiative transition, Energy transfer in different conditions

UNIT IV: Phosphor Lamp and Cathode Ray Phosphors. Studies optical properties on conventional phosphors, oxide phosphors and their applications.

Text Books:

1. G. Blasse Luminescent materials, , Springer 1994
2. B.Valeur Molecular Fluorescence Principal and applications, Wiley, 2001
3. G.H.Dieke Spectra and Energy Levels of Rare Earth Ions in Crystals, , Interscience Publishers, 1968
4. Fluoresecence& Phosphors, Peter Pringshein, Tata Mc Graw Hill, 2003.

NT-DSEC-50801 ELECTRONIC AND MAGNETIC PROPERTIES OF NANOSTRUCTURES
Credit: 4

Subject Code: **NT-DSEC-50801**
Subject Name: *Electronic and Magnetic properties of Nanostructures*
No. of Hours Per Week: *Lectures-4.*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75.*
Duration of End Semester Examination: *Three Hours.*

Unit I: Current, reservoirs, and electron channels, conductance formula for nanostructures, quantized conductance, Local density of states, Ballistic transport, Coulomb blockade, Diffusive transport.

Unit II: Nanomagnetism: Different kind of magnetism in nature: Dia, Para, Ferro, Antiferro, Ferri and Superpara magnetism, important properties in relation to nanomagnetism, particle size effect on magnetic nanoparticles.

Unit III: Electronic properties of nanoparticles: Nanostructures as single electron transistor , field emitter devices, spintronics, nano size magnetic readers and recorders, quantum computing overview, fabrication and properties of nanostructured magnets, probes of nanomagnetic properties, electronics magneto transport, micromagnetic modelling MEMS, design and principle.

Unit IV: Fermi energy and Fermi–Dirac distribution function – Variation of Fermi level with temperature in intrinsic and extrinsic semiconductors. Hall effect – Dilute Magnetic Semiconductors (DMS) and their applications.

Textbooks:

1. Rolf E. Hummel, Electronic Properties of Materials, 4th ed., Springer, NewYork, 2011.
2. Mick Wilson, KamaliKannangara, Geoff Smith, Michelle Simmons, BurkhardRaguse, Nano technology: basic science and emerging technologies, Overseas Press, 2005.
3. Rainer Waser (Ed.), Nanoelectronics and Information Technology: Advanced electronic materials and novel devices (2nd Ed.), Wiley-VCH Verlag, Weiheim, 2005.

References:

1. Victor I Klimov, Semiconductors and Metal Nanocrystals: Synthesis and Electronic and Optical Properties, Marcel Dekker, 2004.
2. D. Brenner, S.Lyshevski, G. Iafrate, William A. Goddard III,Handbook of Nanoscience, Engineering and Technology, CRC Press , 2002.

NT-DSEC-50802 NANOTECHNOLOGY FOR ENERGY DEVICES **Credit: 4**

Subject Code: **NT- DSEC-50802**
Subject Name: *Nanotechnology for Energy Devices*
No. of Hours Per Week: *Lectures – 4.*
Questions to be set: 8 (Eight), **Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75.*
Duration of End Semester Examination: *Three Hours.*

Unit I: Photovoltaic: Sustainable energy, advancement of solar cell with nanotechnology, electrical characteristics of photovoltaic devices, c-Si Solar Cell, advances in c-Si solar PV technology, thin film technology, dye sensitized solar cell.

Unit II: Nanowire- and Nanotube-based Solar cell: Challenges in solar cell, synthesis nanowire by CVD and PLA Si-SiGe heterostructure nanowire, nanowiere solar cell, hybrid nanowire/rod device, Inorganic NWs, Nanowire dye-sensitized solar cell, nanowire and nanotube transparent conductor

Unit III: Advancement of Supercapacitor: Basic principle, Supercapacitor-energeing energy stores, types of supercapacitor, energy storage mechanism in supercapacitor, electrochemical double layer capacitors, pseudo capacitor, hybrid capacito characterization techniques for energy storage mechanism Galvanostatic charge, cyclic voltammetry, naterials for supercapacitor electrode

Unit IV: efficient battery through nano: Limitation of current battery technology, future nanotechnology improvement to batteries, advantage and disadvantage of nanotechnology, nanostructured anode material-graphite and SEI, grapheme and other carbon nanomaterial, nanostructure cathode material, conversion electrode, stretchable electronics,.

Textbooks:

1. D. Infield, Hydrogen from Renewable Energy Sources, 3rd ed., Tylore and Francis, 2014.
2. R.A.Shatwell, Fuel Storage on Board Hydrogen Storage in Carbon Nanostructures, McGraw Hill, 2018.
3. S. David Goodsell, Bionanotechnology: Lessons from Nature, Wiley, Liss, 2004.
4. Nancy E. Carpenter, Chemistry of Sustainable Energy, CRC Press, London, 2e 2017.

References:

1. Vielstich, Handbook of fuel cells: Fuel cell technology and applications, Wiley, CRC Press, 2003.
2. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.

NT-RM-509 Research Methodology & Proposal writing Credit: 4

Subject Code: **NT-RM-509**
Subject Name: **Research Methodology & Proposal writing**
No. of Hours Per Week: *Lectures-4.*
Marks Distribution: *Sessional Works =25, End Semester Examination = 75.*
Duration of End Semester Examination: *Three Hours.*

Unit I: Types of Research: Types, Research process and steps in it, Hypothesis, Research proposals and aspects.

Unit II: Research Design: need, problem definition, variables, research design concepts, literature survey and review, research design process, errors in research.

Unit III: Ethics of Research, Plagiarism, different ways to check palgarism. Patents.

Unit IV: Report Writing: pre-writing considerations, thesis writing, formats of report writing, formats of publications in research journals, use of standard tools like LaTeX.

Suggested Reading

1. C. R. Kothari, *Research Methodology*, 2/e, New Age International Publisher, 2002.
2. S. R. Bajpai, Research Methodology, S. Chand and Sons, 2001.

NT-CC-510 Fabrication of Nanomaterials **Credit: 4**

Subject Code: **NT-CC-510**
Subject Name: *Fabrication of Nanomaterials*
No. of Hours Per Week: *Lectures –4, Tutorial 1*
Questions to be set: 8 (Eight),**Questions to be answered: Any 5** (five)
Marks Distribution: *Sessional Works =25, End Semester Examination = 75*
Duration of End Semester Examination: *Three Hours.*

Unit I: Chemical Methods: Precipitation method, sol gel technique, combustion method, microwave synthesis, sono-chemical synthesis, Chemical Vapour Deposition (CVD) method.

Unit II: Physical Methods: Molecular Beam Epitaxy (MBE), LASER pyrolysis, Laser abalation, Arc discharge, ball milling, ion sputtering.

Unit III: Microscopy techniques: SEM microscopy, TEM microscopy, AFM, STM, EDX.

Unit IV: Spectroscopy techniques: UV-visible spectroscopy, FTIR spectroscopy, Raman Spectroscopy, Auger electron spectroscopy.

Textbooks:

1. S. Bandyopadhyay, Fabrication and application of Nanoamaterials, 1E, Tata Mc Graw Hills, 2019.

References:

1. C. Br´echignac P. Houdy M. Lahmani Nanomaterials and Nanochemistry, Springer, 2006.
2. Makio Naito, Toyokazu Yokoyama, Kouhei Hosokawa,Kiyoshi Nogi Nanoparticle Technology Handbook, 3E, Elsevier, 2018.

NT-CC-600 SEMICONDUCTOR AND NANODEVICES **Credit: 4**

Subject Code: **NT-CC-600**
Subject Name: *Semiconductor and Nanodevices*
No. of Hours Per Week: *Lectures-4.*
Marks Distribution: *Sessional Works =25, End Semester Examination = 75.*
Duration of End Semester Examination: *Three Hours.*

Unit I: Basics of Semiconductor: Energy-band diagrams, density-of-states , equilibrium, charge carriers and doping Carrier transport and excess carriers, drift and diffusion, carrier recombination Structure and properties pn-junction -BJT, MOS, CMOS technology; Light emitting diodes and semiconductor laser

Unit II: Carbon Nanotechnology: Introduction to carbon nanotubes and their applications in various industries, supercapacitors, hydrogen storage; Nanomaterials for solar power: Solar energy materials, Solar energy devices, silicon solar technology for clean energy, Light Emitting Diodes, OLED displays.

Unit III: **Memory devices**: Static and Dynamic Random Access Memories (RAM), Optical and Ferroelectric memories, Electro, Optic Effect, Introduction- longitudinal mode, transfer mode, electro, optic effect in lithium niobate crystals.

Unit IV Sensor devices: Electrochemical Sensors, Gas- sensitive FETs, Resistive nanosemiconductor, Electronic noses, Ferroelectric random access memories, concept of single transistor, Characteristics of Gas sensors; Types of Gas sensors; Solid State Gas sensors: Chemiresistive Gas sensors (Semiconducting Metal Oxide based sensors, Carbon Nano Tube based nanosensors).

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Textbooks:

1. K. Goser, P. Glosekotter, J. Dienstuhl, Nanoelectronics and Nanosystems: From transistors to molecular devices, Springer, 2004.
2. Rainer Waser (Ed.), Nanoelectronics and information technology: Advanced electronic materials and novel devices (2nd Ed.), Wiley, VCH Verlag, Weiheim, 2005.
3. Mick Wilson, KamaliKannangara, Geoff Smith, Michelle Simmons, BurkhardRaguse, Nano technology: basic science and emerging technologies, Overseas Press, 2005.
4. Victor I Klimov, Semiconductors and Metal Nanocrystals: Synthesis and Electronic and Optical Properties, Marcel Dekker, 2004.

References:

1. Kenneth J. Klabunde,Nanoscale Materials in Chemistry. , John Wiley & Sons, Inc., 2001.

YEAR IISEMESTER III

NT-602-DSEC DISSERTATION: PHASE-I

Subject Code: *NT-600-DSEC*
Subject Name: *Dissertation: Phase-I*
Marks Distribution: *Internal works = 125, End Semester Examination = 375.*
Duration of End Semester Examination: 3 (*Three) Hours.*

The primary objective of this course is to develop in student the capacity for analysis and judgment and the ability to carry out independent investigation in design /development through a dissertation work involving creativity, innovation and ingenuity. The work must start with comprehensive literature survey consultation with allotted supervisor from the department and critical appreciation thereof so as to select research problem the student wishes to work on.

Each student will carry out independent dissertation under the supervision of a department faculty member (s) who will be called Supervisor(s). However, based on the requirement under the supervision of the Supervisor can cop Joint-supervisor from other teachers from other allied Departments. In no case more than two supervisors can be associated with one dissertation work. The students may carry out the dissertation work at reputed University/Institute/Industry with prior permission from the Supervisor and the Department.

The dissertation involving design/ fabrication/ testing/ computer simulation/ case studies etc. which commences in the III Semester will be completed in IV Semester. The evaluation of the dissertation phase–I besides approval of the dissertation topic of the students will be done by a committee constituted as under:

Head of Department	: Chairperson
M Tech Coordinator / Sr. Faculty	: Member Secretary
Respective dissertation supervisor	: Member
All faculties in the Department	: Member(s)
External expert	: To be appointed by the University

The student will be required to submit two copies of his/her report to the department for record (one copy each for the department/library/controller of examination/supervisor and participating faculty member (s)).

Supervisor allocation: Based on the merit and choice of the student maximum 4 students can be allotted to each faculty of the department.

NT-606-DSEC DISSERTATION: PHASE-II

Subject Code: **NT-606-DSEC**
Subject Name: *Dissertation: Phase-II*
Marks Distribution: Internal works *= 125, End Semester Examination = 375.*
Duration of End Semester Examination: 3 (*Three) Hours.*

The dissertation started in 3rd Semester will be completed in 4th Semester and will be evaluated in the following manner.

Internal Assessment

Internal Assessment (class work evaluation) will be effected as per ordinance through interim report, presentation and discussion thereon by the following committee of three persons:

Head of Department	: Chairperson
M. Tech Coordinator / Sr. Faculty	: Member Secretary
Respective dissertation supervisor(s)	: Member (s)
All faculties in the Deptt	: Member(s)

The Committee will decide whether the work done by the student is sufficient for M.Tech degree and allow student to submit.

External Assessment

Final dissertation will be assessed by a panel of examiners consisting of the following:

Head of Department	: Chairperson
Respective Supervisor(s)	: Member(s)
All faculties in the Deptt	: Member(s)
External expert	: To be appointed by the University

Note: The External Expert must be from the respective area of specialization. The Chairperson and M Tech Coordinator with mutual consultation will divide the submitted dissertations into groups depending upon the area of specialization and will recommend the list of experts for each group separately to the Dean, SOT for selecting the examiners with the note that an external expert should be assigned a maximum of FIVE dissertations for evaluation in a session. The student will be required to submit FIVE copies of his/her report to the M Tech Coordinator and the University for record and processing.