प्रतिष्ठित संस्थान
INSTITUTION OF EMINENCE
राष्ट्रीय अपेक्षाएँ, वैश्विक मानक
National Needs, Global Standards
हैदराबाद विश्वविद्यालय
UNIVERSITY OF HYDERABAD

Outcome Based Education (OBE) Document

M.Tech. (Nano Science and Technology)

School of Engineering Sciences and Technology

हैदराबाद विश्वविद्यालय
University of Hyderabad

Vision Statement

To be a centre of excellence for learning, training, research and development and entrepreneurial attitude in engineering sciences and technology.

Mission Statements (MS)

- To produce scientists, engineers and technologists through training programs in Nano Science and Technology, Materials Engineering, Manufacturing Science and Technology and other current areas of Engineering Sciences and Technology.

- To create a culture of addressing and solving the short-term and long-term pertinent problems in the society through engineering interventions.

- To encourage inter-disciplinary and collaborative research both at national and international levels.

- To carry out sponsored research and consultancy projects funded by national and international agencies and industries.

Program Educational Objectives (PEOs)

PEO1. To attain world-class quality in learning (theory and practical) and research related to engineering sciences and technology.
PEO2. To provide comprehensive and interdisciplinary knowledge on analyses, design, and creation of novel and environmentally benign engineering solutions for short-term and long-term pertinent problems in the society.
PEO3. To give a comprehensive hands-on training in the theory and experiments related to processing, characterization, testing of advanced materials and engineering components.
PEO4. To produce high quality and industrially relevant human resource for possible employment in industries, and academic and research organizations.

Mapping PEOs with MS

	MS-1	MS-2	MS-3	MS-4
PEO-1	3	3	3	2
PEO-2	3	3	3	2
PEO-3	2	3	2	2
PEO-4	3	2	2	2

‘3’ – ‘high-level’ mapping; ‘2’ – ‘Medium-level’ mapping; ‘1’ – ‘Low-level’ mapping;

Program Outcomes (POs)

On completion of the MTech (Nano Science and Technology) program at School of Engineering Sciences and Technology, the students will be able to:

PO-1. apply the basic science and engineering knowledge and course-specific engineering fundamentals to solve the problems in the society

PO-2. identify or formulate complex engineering problems and design specific and generic solutions for the same

PO-3. analyze the identified (or formulated) problems and conduct systematic and interdisciplinary research to solve them and/or to provide valid conclusions

PO-4. select and apply appropriate resources, and contemporary techniques and tools while solving the identified (or formulated) problems with a complete understanding of the limitations

PO-5. illustrate the complete cognizance of public health and safety, environmental safety, and cultural, societal and legal implications while solving the identified (or formulated) problems

PO-6. evaluate the sustainability, impact and implications of their work on solving the identified (or formulated) problems

PO-7. summarize effectively and explain the identified (or formulated) problems and their solutions and the methodology followed to solve the problems to the appropriate professional community as well as to the general public

PO-8. perform effectively as an individual and as a member (or a leader) of a team under inter-disciplinary national and international contexts.

PO-9. apply the project management skills under inter-disciplinary scenarios

PO-10. demonstrate professional responsibility and ethics

PO-11. recognize the need to develop interest in life-long learning to keep-up with the contemporary science and engineering

PO-12. To impart approaches in general problem solving, professional and ethical values, principles of team work and written and oral communication skills

PO-13. To provide an environment that fosters the culture of life-long learning

Course Structure

Semester I

Subject Type	Subject Code	Subject Name	L-T-P	Credits
Core	NT401	Elements of Nanoscience & Technology	3-0-0	3
Core	MT402	Material Characterization Methods-I	3-0-0	3
Core	NT403	Synthesis and Processing of Nanomaterials	3-0-0	3
Core	NT404	Physical Behavior of Nanomaterials	3-0-0	3
Core	NT405	Synthesis, Processing and Characterization Lab-I	0-0-4	4
Core	MT407	Advanced Engineering Mathematics	3-0-0	3
Elective	NT60X	Elective-I	3-0-0	3
		Total		**22**

L-Lecture; T-Tutorial; P-Practical; MT-Courses offered in MTech (Materials Engineering) and considered common to MTech programs in the school

Semester II

Subject Type	Subject Code	Subject Name	L-T-P	Credits
Core	NT451	Nanofabrication	3-0-0	3
Core	MT452	Materials Modeling	3-0-0	3
Core	MT453	Material Characterization Methods-II	3-0-0	3
Core	NT454	Nanotechnology Infrastructure and Safety	3-0-0	3
Core	NT455	Synthesis, Processing and Characterization Lab-II	0-0-4	4
Core	NT495	Seminar I and Comprehensive Viva	0-0-2	2
Elective	NT65X	Elective I	3-0-0	3
Elective	NT65X	Elective II	3-0-0	3
		Total		**24**

L-Lecture; T-Tutorial; P-Practical; MT-Courses offered in MTech (Materials Engineering) and considered common to MTech programs in the school

Semester III

Subject Code	Subject Name	L	T	P	Credits
NT498	Project Part-I	0	0	12	12
NT496	Project Seminar-I	0	0	8	8
	Total				**20**

L-Lecture; T-Tutorial; P-Practical;

Semester-IV

Subject Code	Subject Name	L	T	P	Credits
NT499	Project Part-II	0	0	12	12
NT497	Project Seminar-II	0	0	8	8
	Total				**20**

L-Lecture; T-Tutorial; P-Practical;

Total Credits (I+II+III+IV semesters) = 22+24+20+20 = **86**

List of Electives (Semester II)

(Any two (2) from the following list of subjects and those relevant and offered in other MTech courses)

NT601 Nanocarbons
NT651 Smart Materials for Sensor and Energy Applications
NT652 Nanomechanics

Program Specific Outcomes (PSOs)

PSO-1 demonstrate comprehensive knowledge on nanomaterials processing, characterization and testing
PSO-2 apply knowledge on modelling and designing new nanomaterials

PSO-3 conduct systematic experimentation to produce new nanomaterials and products
PSO-4 select appropriate technologies leading to new products and processes for different applications based on nanotechnology

Mapping of POs and PSOs with PEOs

	PEO-1	PEO-2	PEO-3	PEO-4
PO-1	3	3	3	2
PO-2	3	3	3	2
PO-3	3	3	3	2
PO-4	3	3	3	2
PO-5	2	2	2	1
PO-6	2	2	2	1
PO-7	3	2	2	1
PO-8	2	2	2	1
PO-9	2	2	2	1
PO-10	2	2	2	1
PO-11	2	2	2	1
PO-12	2	2	2	1
PO-13	3	2	2	1
PSO-1	3	3	3	2
PSO-2	3	3	2	2
PSO-3	3	3	3	1
PSO-4	3	3	3	1

‘3’ – ‘high-level’ mapping; ‘2’ – ‘Medium-level’ mapping; ‘1’ – ‘Low-level’ mapping;

Course Outcomes (COs)

Subject Code: **NT401**
Title of the Course: **Elements of Nanoscience and Technology**
L-T-P: 3-0-0 Credits: 3

Prerequisite Course/Knowledge (If any): Basic knowledge of solid state physics and chemistry

After completion of this subject successfully, the students will be able to:

CO-1: apply the fundamentals of solid state physics and chemistry to nanoscience.
CO-2: correlate physical behavior of materials at the nanoscale with quantum mechanics
CO-3: analyse the requirement of statistical mechanics for understanding the physical and chemical behavior of materials at the nanoscale
CO-4: apply the knowledge gained to suggest different applications of nanoscience and technology.

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	2	2	3	3	3	3	2	2	2	2	2	1	1	3	2	2	1
CO2	2	2	3	3	2	2	2	2	2	2	2	1	1	2	2	2	1
CO3	2	2	3	3	2	2	2	2	2	2	2	1	1	2	2	2	1
CO4	2	2	3	1	1	2	2	2	2	2	2	1	1	2	2	2	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Size effects: Effect of dimensionality of solids on surface to volume ratio, band structure, tunneling and electron spins. Impact of size effects on magnetic, optical and transport properties of solids;

Unit 2: Brief introduction to Quantum mechanics: Schrodinger’s equations. Harmonic Oscillator, particle in a box, potential well problems, density of states, quantum confinement and impact on physical behavior of solids;

Unit 3: Statistical Mechanics: Macroscopic systems/Systems constituted by many particles: Entropy and kinetics; probability distribution for non-interacting particles; Entropy and the Boltzmann distribution with examples; The equipartition theorem; Partition function and its application in the case of ideal gas; application to nanoscale systems;

Unit 4: Applications: Zero, one, and two dimensional nanostructures, catalysts, sensors, spintronics, tunneling based devices etc.

Suggested Books:

1. Nanotechnology: A Gentle Introduction to the Next Big Idea, M. Ratner and D. Ratner.
2. Nanotechnology for Dummies, R. Booker and E. Boysen.
3. Introduction to Nanoscience, S. M. Lindsay.

Subject Code: **MT402**
Title of the Course: **Material Characterization Methods-I**
L-T-P: 3-0-0 Credits: 3

Prerequisite Course/Knowledge (If any): Basic concepts of thermodynamics such as temperature, pressure, system, properties, process, state, cycles and equilibrium

After completion of this subject successfully, the students will be able to:

CO-1: explain the fundamentals of microscopy
CO-2: compute thermodynamic properties like enthalpy, entropy, free energy of metallurgical reactions
CO-3: analyze the phase equilibria, unary and binary phase diagrams of any complexity
CO-4: explain thermodynamics of nucleation, oxidation and reduction and electrolysis

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	3	3	3	2	2	2	2	1	1	1	3	2	1	1
CO2	2	2	3	3	3	2	2	3	2	2	1	1	1	2	2	1	1
CO3	2	3	3	3	2	2	2	2	2	2	1	1	1	2	2	1	1
CO4	2	2	3	1	1	2	2	2	2	2	2	1	1	2	2	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Fundamentals: Resolution; magnification; contrast; scattering; interference; diffraction etc.;

Unit 2: Microscopy/diffraction techniques: Light microscopy; scanning electron microscopy (SEM) ; transmission electron microscopy/diffraction (TEM) ; x-ray diffraction (XRD); neutron diffraction; scanning probe microscopy;

Unit 3: Spectroscopic techniques: Electron induced x-ray emission (EDS) in SEM and TEM; Electron energy loss spectroscopy (EELS) in TEM; x-ray photoelectron spectroscopy (XPS);

Unit 4: Characterization of materials at the micrometer nanometer and atomic scale using various microscopy/diffraction methods;

Suggested Books:

1. Materials Characterization Techniques, Sam Zhang, Lin Li, Ashok Kumar.
2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Y. Leng.
3. Practical Materials Characterization, M. R. Sardela
4. Lecture notes and handouts

Subject Code: **NT403**
Title of the Course: **Synthesis and Processing of Nanomaterials**
L-T-P: 3-0-0   Credits: 3

Prerequisite Course/Knowledge (If any): -

After completion of this subject successfully, the students will be able to:

CO-1: perform simple geometric calculations of surface energy, coordination number, and volume fraction related to nanoscale properties
CO-2: analyze the advantages and limitations of several synthetic methods for fabrication of in-organic nanoparticles, one-dimensional nanostructures (nanotubes, nanorods, nanowires), thin films, nanoporous materials, and nanostructured bulk materials
CO-3: select an appropriate physical method in preparing any given nanomaterial
CO-4: select an appropriate chemical method in preparing any given nanomaterial
CO-5: select best suited method for fabricating any given nanostructured material

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	1	1	1	1	1	1	1	1	1	1	1	3	3	1	1
CO2	3	3	1	3	1	1	1	1	1	1	1	1	1	3	3	1	1
CO3	3	3	1	3	1	1	1	1	1	1	1	1	1	3	3	1	1
CO4	3	3	1	3	1	1	1	1	1	1	1	1	1	3	3	1	1
CO5	3	3	1	3	1	1	1	1	1	1	1	1	1	3	3	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Introduction to nanomaterials: nanostructured surface and interfaces, effect of particle size on properties of nanomaterials, Synthesis (bottom-up) and manufacturing (top-down) of nanomateri-als

Unit 2: Nanostructures of Zero dimension: Homogenous nucleation, Heterogeneous nucleation, Kinetic controlled synthesis

Unit 3: Nanostructures of one dimension: Crystalline growth, Template based synthesis

Unit 4: Nanostructures of two dimensions: Fundamentals of thin film growth, physical vapour deposition, chemical vapour deposition, atomic layer deposition, self-assembly, Langmuir-Blodgett films, Sol-Gel films, electrochemical deposition

Unit 5: Nanostructures of three dimensions: Nanocomposites, Severe plastic deformation process: Friction stir processing (FSP) and equi-channel angular pressing

Suggested Books:

1. Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Guozhong Cao.
2. Nanomaterials, Nanotechnologies and Design: An introduction for Engineers and Architects, M.J. Ashby, P.J. Ferreira, D.L. Schodek.
3. Nanotechnology: Principles and Practices, S.K. Kulkarni.

Subject Code: **NT404**
Title of the Course: **Physical Behavior of Nanomaterials**
L-T-P: 3-0-0 Credits: 3

Prerequisite Course/Knowledge (If any): Basic knowledge of physics, chemistry and materials science at bachelor level

After completion of this subject successfully, the students will be able to:

CO-1: apply the basic knowledge of atomic structure and bonding to nanoscale systems.
CO-2: analyse the effect of dimensionality on semiconducting, electrical and dielectric properties of nanomaterials
CO-3: analyse the effect of dimensionality on magnetic properties of nanomaterials
CO-4: analyse the effect of dimensionality on optical properties of nanomaterials.
CO-5: explain applications of electrical, dielectric, magnetic, semiconducting and optical materials in nanotechnology.

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	2	1	1	1	1	1	1	1	1	1	3	2	3	2
CO2	3	1	2	2	1	1	2	1	1	1	1	1	1	3	3	2	2
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	2	3	1	1
CO4	2	2	1	1	1	1	1	1	1	1	1	1	1	3	2	1	1
CO5	2	2	1	1	1	1	1	1	1	1	1	1	1	3	2	2	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping; ‘left blank’–not applicable;

Detailed Syllabus:

Unit 1: Introduction: Atomic structure, electronic configuration, periodic table, bonding forces and energies, ionic bonding, covalent bonding, metallic bonding, van der Waals bonding, hydrogen bonding, dipole bonding;

Unit 2: Electrical and Dielectric Properties: band structure in solids, conduction in terms of band structure and atomic bonding model, electrical resistivity of metals, intrinsic and extrinsic semiconductors, dielectric behavior – capacitance, types of polarization, frequency dependence of dielectric constant, dielectric strength, ferroelectricity, piezoelectricity. Influence of dimensionality on transport properties. Examples of applications in nanotechnology;

Unit 3: Magnetic Properties: Basic concepts; diamagnetism and paramagnetism; ferromagnetism, antiferro- and ferrimagnetism; soft and hard magnetic materials. Influence of dimensionality on magnetic behavior. Examples of applications in nanotechnology;

Unit 4: Optical Properties: Refractive index, non-linear optical properties, Optical band gap: effect of quantum confinement, photoluminescence and fluorescence: introduction and difference in selection rules between bulk and nanoscale systems, nanophotonics. Examples of applications in nanotechnology;

Suggested Books:

1. Materials Science and Engineering, William D Callister, Jr.
2. Electronic Properties of Material, Rolf E. Hummel.
3. Materials Science for Engineers, James F. Shackelford.
4. Science and Engineering of Materials, Askeland.
5. Introduction to Solid State Physics, C. Kittel.
6. Elements of Materials Science and Engineering, Van Vlack and H. Lawrence.

Subject Code: **NT405**
Title of the Course: **Synthesis, Processing and Characterization Lab-I**
L-T-P: 0-0-4 Credits: 4

Prerequisite Course/Knowledge (If any): Synthesis and processing of nanomaterials & Materials characterization methods-I

After completion of this subject successfully, the students will be able to:

CO-1: synthesize nanomaterials by physical methods such as ball milling
CO-2: synthesize nanomaterials by chemical methods such as colloidal method
CO-3: record and analyze X-ray diffractogram of any nanomaterial
CO-4: record and analyze electron micrograph data of any nanomaterial
CO-5: determine the average particle size and zeta potential by DLS technique
CO-6: determine the surface area and pore size distribution by BET method
CO-7: communicate the results of all experiments in the form of a written technical report

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	3	2	2	3	3	2	2	3	2	2	3	3	2	3
CO2	3	3	3	3	2	2	3	3	2	2	3	2	2	3	3	2	3
CO3	2	2	2	3	1	1	1	2	2	2	2	2	2	2	3	2	1
CO4	2	2	3	3	1	2	3	2	2	2	2	2	2	2	3	1	1
CO5	2	2	3	3	1	2	3	2	2	2	2	2	2	2	3	1	1
CO6	2	2	2	2	1	2	3	3	3	2	2	2	2	1	1	1	1
CO7	2	2	2	2	1	2	3	3	3	2	2	2	2	1	1	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

1. Synthesis of 0D nanoparticles (Ex: Au) - Colloidal Method
2. Particle size reduction in metals by mechanical milling
3. Record and understand size, shape and size distribution of standard nanomaterials using electron microscopy (SEM and TEM).
4. Determination of Crystallite size of a standard nanocrystalline powder metal sample by using X-ray diffraction analysis and correlating it with dark field TEM image and electron diffraction analysis.
5. Record and understand standard XRD pattern of a nanocrystalline material using Rietveld refinement and Williamson and Hall plot.
6. Determination of average particle size and zeta potential by DLS.
7. Determination of specific surface area and pore size distribution by BET.

Subject Code: **MT407**
Title of the Course: **Advanced Engineering Mathematics**
L-T-P: 3-0-0   Credits: 3

Prerequisite Course/Knowledge (If any): BE/BTech level mathematics knowledge

After completion of this subject successfully, the students will be able to:

CO-1: solve the problems using the principles of linear vector spaces and matrices
CO-2: solve ordinary and partial differential equations analytically with relevant examples in Materials Engineering
CO-3: practice integral transforms and apply to differential equations
CO-4: assess statistical fits
CO-5: solve differential, integral, approximation, interpolation and optimization problems numerically

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	3	2
CO2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	3	2
CO3	2	2	2	2	1	1	1	1	1	1	1	1	1	2	3	3	2
CO4	3	3	3	3	1	1	1	1	1	1	1	1	1	3	3	3	3
CO5	3	3	3	3	1	1	1	1	1	1	1	1	1	3	3	3	3

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Linear vector spaces and matrices: Functions as elements of a linear vector space; Basis sets and expansion; Operators and matrix representations; Eigen value problem and diagonalization;

Unit 2: Differential calculus: Solutions to ordinary differential equations; Variational calculus; Applications of partial derivatives – Lagrange multipliers;

Unit 3: Integral transforms: Fourier and Laplace transforms; Their properties; Equivalence of conjugate Fourier spaces; Application to differential equations with examples;

Unit 4: Probability and statistics: Random variables and joint distributions; Functions of random variables; Basic statistical estimators; Method of linear least squares; Random processes;

Unit 5: Numerical methods: Numerical differentiation and integration; Interpolation and polynomial approximations; Numerical optimization; Introduction to MATLAB commands;

Suggested Books:

1. Advanced Engineering Mathematics, M. D. Greenberg.
2. Mathematical Methods for Physics and Engineering, K. F. Riley and M. P. Hobson.
3. Mathematical Physics - A Modern Introduction to its Foundations, Sadri Hassani.
4. Mastering MATLAB 7, D. Hanselman and B. Littlefield.

Subject Code: **NT451**
Title of the Course: **Nanofabrication**
L-T-P: 3-0-0 Credits: 3

Prerequisite Course/Knowledge (If any): Basic fundamentals of electronic materials, nanomaterials and nanotechnology

After completion of this subject successfully, the students will be able to:

CO-1: explain the processes required for nanofabrication of materials
CO-2: develop fabrication processes for making nanomaterials in one, two and three dimensions
CO-3: apply the engineering knowledge to develop nanofabrication process for engineering applications
CO-4. select appropriate nanofabrication process for any given application

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	2	2	2	1	1	1	1	1	1	1	1	1	3	2	3	2
CO2	3	2	2	2	1	1	2	1	1	1	1	1	1	3	3	2	2
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	2	3	1	1
CO4	2	2	1	1	1	1	1	1	1	1	1	1	1	3	2	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Suggested Books:

Subject Code: **MT452**
Title of the Course: **Materials Modelling**
L-T-P: 3-0-0 Credits: 3

Prerequisite Course / Knowledge (If any): BE/BTech level knowledge in materials science and mathematics

After completion of this subject successfully, the students will be able to:

CO-1. describe the input and output parameters in density functional theory calculations
CO-2. explain the elements of computational materials thermodynamics
CO-3. explain the Monte-Carlo methods for modeling of materials
CO-4. discuss the molecular dynamics methods of modelling of materials
CO-5. calculate the material properties by applying the learnt modeling and simulation tools

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	3	2
CO2	3	3	3	2	1	1	1	1	1	1	1	1	1	2	3	3	2
CO3	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	3	2
CO4	2	2	2	2	1	1	1	1	1	1	1	1	1	3	2	3	2
CO5	3	3	3	3	1	1	1	1	1	1	1	1	1	3	3	3	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Density functional theory: Introduction to density functional theory; Thermodynamic quantities; Density of states; Software packages;

Unit 2: Computational Thermodynamics: Generation of thermochemical and phase equilibria information; Models for Gibbs energy; Thermodynamic assessment; Gibbs energy database creation; Diffusion modelling; Software packages;

Unit 3: Monte Carlo Methods: Random variables, Generation of different distributions, Metropolis algorithm, Phase transitions (magnetic systems as example);

Unit 4: Molecular Dynamics: Newtonian dynamics, Finite-difference methods, Molecular dynamics of hard spheres, phase transitions (solid-liquid transformation as example). Stochastic processes, Markov chains, Diffusion models based on random walks, Transport phenomena (heat conduction as an example);

Unit 5: Laboratory component: Phase diagram calculation o Thermodynamic property diagram calculation of Random number generation and testing for randomness o Construction of ensembles of different standard distributions o Monte Carlo simulations based on Metropolis algorithm;

Suggested Books:

1. Sidney Yip (ed), Handbook of Materials Modeling, Volumes A and B, (Springer, 2005).
2. Fong C Y, Topics in Computational Materials Science (Singapore: World Scienti_c, 1999).
3. Landau R H, Paez M J, and Bordeianu C C, A Survey of Computational Physics (Princeton: Princeton University Press, 2008).
4. Martin R M, Electronic Structure (Cambridge: Cambridge University Press, 2004).
5. Hoover WG, Computational Statistical Mechanics (Elsevier, 1991).
6. Allen M P and Tildesley D J, Computer Simulation of Liquids (Oxford: Oxford University Press, 1989).
7. Haile J M, Molecular Dynamics Simulation: Elementary Methods (New York: Wiley, 1992).
8. Rapaport DC, The Art of Molecular Dynamics Simulations, Second Edition, (Cambridge University Press, 2004).
9. Landau and Binder, A Guide to Monte Carlo Simulations in Statistical Physics, 2nd.ed. (CUP, 2005).

10. Kalos M H and Whitlock P A, Monte Carlo Methods Volume I: Basics (Wiley, 1996).
11. Saunders N and Miodownik A P, CALPHAD (Calculation of Phase Diagrams): A Comprehensive Guide, (Oxford, Pergamon, 1998).

Subject Code: **MT 453**
Title of the Course: **Material Characterization Methods-II**
L-T-P: 3-0-0 Credits: 3

Prerequisite Course/Knowledge (If any): Basic knowledge of physics, chemistry and materials science at bachelor level

After successful completion of this subject successfully, the students should be able to,

CO-1: apply the knowledge of various physical methods to characterize materials
CO-2: apply the knowledge of various spectroscopic techniques to characterize materials
CO-3: characterize the material based on electrical, electronic and dielectric properties
CO-4: determine ferroelectric and dielectric properties of materials
CO-5: apply different methods of thermal analysis to characterize materials

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	2	1	1	1	1	1	1	1	1	1	3	2	3	1
CO2	3	1	2	2	1	1	2	1	1	1	1	1	1	3	3	2	1
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	2	3	1	1
CO4	2	2	1	1	1	1	1	1	1	1	1	1	1	3	2	1	1
CO5	3	2	1	2	1	2	1	1	1	1	1	1	1	3	1	2	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Physical Characterizations – Particle size/shape/distribution, Surface area, Porosity, Density, Flow property
Unit 2: Chemical Characterizations – Elemental analysis (EDS/WDS/EPMA), Raman, IR/FTIR, UV-Vis, SIMS, XPS
Unit 3: Electrical, Electronic and Dielectric Characterizations – I-V, C-V, carrier type and concentration, Dielectric constant and its temp dependence, capacitance and loss factor, Impedance spectroscopy
Unit 4: Ferroelectric and Magnetic Characterizations – Electric field dependence of Polarization (P-E loop), piezoelectric coefficients, M vs H, M vs T, Magnetic permeability/susceptibility, energy product etc
Unit 5: Thermal and Optical Characterizations – DTA, TGA, DSC, Thermal conductivity, Thermal expansion, PL, Ellipsometry etc

Suggested Books:

1. “Materials Characterization Techniques” by Sam Zhang, Lin Li, and Ashok Kumar CRC Press, Taylor and Francis Group
2. “Physical Methods for Materials Characterization” by Peter E. J. Flewitt and Robert K Wild, CRC Press, Taylor and Francis Group
3. “Concise Encyclopedia of Materials Characterization”, ed. Robert W Cahn and Eric Lifshin, Pergamon Press
4. Lecture notes and handouts

Subject Code: **NT454**
Title of the Course: **Nanotechnology Infrastructure and Safety**
L-T-P: 3-0-0 Credits: 3

Prerequisite Course/Knowledge (If any): -

After completion of this subject successfully, the students will be able to:

CO-1:
CO-2:
CO-3:
CO-4:
CO-5:

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1																	
CO2																	
CO3																	
CO4																	
CO5																	

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed syllabus:

Suggested Books:

Subject Code: **NT455**
Title of the Course: **Synthesis, Processing and Characterization Lab-II**
L-T-P: 0-0-4 Credits: 4

Prerequisite Course/Knowledge (If any): -

After completion of this subject successfully, the students will be able to:

CO-1: apply physical methods for synthesis of nanomaterials
CO-2: apply chemical methods for synthesis of nanomaterials
CO-3: record and analyze spectroscopic data of any nanomaterial
CO-4: record and analyze thermal characteristics of any nanomaterial
CO-5. communicate the results of all experiments in the form of a written technical report

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	3	2	2	3	3	2	2	3	2	2	3	3	2	3
CO2	3	3	3	3	2	2	3	3	2	2	3	2	2	3	3	2	3
CO3	2	2	2	3	1	1	1	2	2	2	2	2	2	2	3	2	1
CO4	2	2	3	3	1	2	3	2	2	2	2	2	2	2	3	1	1
CO5	2	2	3	3	1	2	3	2	2	2	2	2	2	2	3	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed syllabus:

1. Preparation of 2D nanomaterials by PVD techniques
2. Synthesis of few layered graphene oxide by Hummers method
3. Record and evaluation of spectroscopic (Raman, FTIR, UV-Vis etc.,) data of a given nano-material.
4. Record and evaluation of different thermal characteristics of a given nanomaterial using TG/DTA and DSC analysis.

Subject Code: **NT495**
Title of the Course: **Seminar I and Comprehensive Viva**
L-T-P: 0-0-2   Credits: 2

Prerequisite Course/Knowledge (If any): -

After completion of this subject successfully, the students will be able to:

CO-1: demonstrate skills to prepare scientific/technical presentation
CO-2: demonstrate skills in orally delivering scientific and technical presentations
CO-3: demonstrate skills in answering logical questions in Nanoscience and Technology
CO-4: demonstrate skills in answering scientific/technical questions in Nanoscience and Technology

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	2	2	2	2	2	2	2	2	1	1	3	3	3	3
CO2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO3	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO4	3	3	3	3	2	2	2	2	2	2	2	1	1	3	2	2	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed syllabus:

Handouts will be given to the students in class

Electives

Subject Code: **NT601**
Title of the Course: **Nanocarbons**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course/Knowledge (If any): Basics in materials science, physics/chemistry at bachelors level

After completion of this subject successfully, the students will be able to:

CO-1: explain the fundamentals of bonding and consequences in various carbon allotropes
CO-2: apply the principles of materials' synthesis to nanocarbons
CO-3: explain the morphology and structure stabilization in nanocarbons
CO-4: explain different characteristics of nanocarbons
CO-5: apply the knowledge acquired to demonstrate various applications of nanocarbons

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2	2
CO2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
CO3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
CO4	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
CO5	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1

'3'–'high-level' mapping; '2'–'Medium-level' mapping; '1'–'Low-level' mapping;

Detailed Syllabus:

Unit1: Importance of the element Carbon; Carbon allotropes; Nano carbons (fullerenes, tubes, fibers and graphene);

Unit 2: Synthesis methods of nano carbons; structure and morphology stabilization; growth mechanisms of nano carbons;

Unit 3: Characterization of nano carbons; Different characteristics of nano carbons; size confinement aspects; Electrons in nano carbons;

Unit 4: Various applications (related to energy, sensors, composites etc.,) of nano carbons in correlation to their characteristics;

Suggested Books:

1. Introduction to Nanotechnology- Charles P. Poole Jr and Frank J. Owens.
2. Hand book of Nanotechnology, Bharat Bhushan.
3. Carbon Nanotubes Properties and Applications- Michael J. O'Connell.
4. Graphene – Synthesis, Characterization, Properties and Applications, J. R. Gong.
5. Science of Fullerenes and carbon nanotubes, M. S. Dresselhaus and P. C. Eklund.

Subject Code: **NT651**
Title of the Course: **Smart Materials for Sensor and Energy Applications**

L-T-P: 3-0-0   Credits: 3
Prerequisite Course/Knowledge (If any): Basics in nanomaterials and nanotechnology

After completion of this subject successfully, the students will be able to:

CO-1: explain understand the key concepts of sensors, energy materials and related phenomena
CO-2: develop nanomaterials-based smart materials with unique properties for sensors and energy applications
CO-3: apply the engineering skills to develop sensors for different applications
CO-4: apply appropriate testing methods for different types of sensors

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	3	1	1	1	1	1	1	1	1	1	2	2	2	2
CO2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2	2
CO3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
CO4	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Suggested Books:

Subject Code: **NT652**
Title of the Course: **Nanomechanics**

L-T-P: 3-0-0   Credits: 3
Prerequisite Course/Knowledge (If any): -

After completion of this subject successfully, the students will be able to:

CO-1:
CO-2:
CO-3:
CO-4:

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1																	
CO2																	
CO3																	
CO4																	

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Suggested Books:

Course Code: **NT498**
Title of the Course: **Project Part-I**

L-T-P: 0-0-12   Credits: 12
Prerequisite Course/Knowledge (If any): Theoretical and practical knowledge gained from the 1st two semesters

After completion of this subject successfully, the students will be able to:

CO-1: explain the problem definition of the project assigned
CO-2: design and explain the experiments and/or theoretical work to be carried out
CO-3: explain about the resources required to conduct the project work
CO-4: demonstrate a part of project work done, if any

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	3	3	3	2	2	2	2	2	2	2	3	3	3	3
CO2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
CO3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
CO4	3	3	3	3	3	3	2	2	2	2	2	2	2	3	2	2	2

'3'–'high-level' mapping; '2'–'Medium-level' mapping; '1'–'Low-level' mapping;

Detailed syllabus:

A problem will be given and explained by the supervisor;
Experimental and/or theoretical plan shall be given by the supervisor;
Continuous guidance till the end of the project shall be given by the supervisor;

Course Code: **NT496**
Title of the Course: **Project Seminar-I**
L-T-P: 0-0-8   Credits: 8
Prerequisite Course/Knowledge (If any): Theoretical and practical knowledge gained from the 1st two semesters and seminar subject during the 2nd semester of the course

After completion of this subject successfully, the students will be able to:

CO-1: demonstrate skills to prepare scientific/technical presentation on the project assigned
CO-2: demonstrate skills in orally delivering scientific/technical presentation on the project assigned
CO-3: demonstrate skills in answering logical questions related to the project assigned
CO-4: demonstrate skills in answering scientific/technical questions related to the project assigned

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO3	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO4	3	3	3	3	2	2	2	2	2	2	2	1	1	2	2	2	2

'3'–'high-level' mapping; '2'–'Medium-level' mapping; '1'–'Low-level' mapping;

Detailed syllabus:

Continuous guidance till the end of the project shall be given by the supervisor;
Course Code: **NT499**
Title of the Course: **Project Part-II**

L-T-P: 0-0-12 Credits: 12
Prerequisite Course/Knowledge (If any): Theoretical and practical knowledge gained from the 1st two semesters

After completion of this subject successfully, the students will be able to:

CO-1: demonstrate skills in systematically carrying out the experiments and/or theoretical work in order to find out specific and/or generic solutions to the problem given
CO-2: demonstrate skills to optimally utilize the resources and finish the project in specified time frame
CO-3: analyze critically the obtained results
CO-4: demonstrate skills to give both specific and generic conclusions

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	3	3	3	2	2	2	2	2	2	2	3	3	3	3
CO2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
CO3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
CO4	3	3	3	3	3	3	2	2	2	2	2	2	2	3	2	2	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed syllabus:

Continuous guidance till the end of the project shall be given by the supervisor;

Course Code: **NT497**
Title of the Course: **Project Seminar-II**
L-T-P: 0-0-8 Credits: 8
Prerequisite Course/Knowledge (If any): Theoretical and practical knowledge gained from the 1st two semesters and seminar subject during the 2nd semester of the course

After completion of this subject successfully, the students will be able to:

CO-1: demonstrate skills to prepare scientific/technical presentation on the project assigned
CO-2: demonstrate skills in orally delivering scientific/technical presentation on the project assigned
CO-3: demonstrate skills in answering logical questions related to the project assigned
CO-4: demonstrate skills in answering scientific/technical questions related to the project assigned

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO3	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO4	3	3	3	3	2	2	2	2	2	2	2	1	1	2	2	2	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed syllabus:
Continuous guidance till the end of the project shall be given by the supervisor;