VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELAGAVI

Syllabus

M.Tech., in Nanotechnology

(Specialization in Nanotechnology / Nanoscience and Technology)

Choice Based Credit System (CBCS) and Outcome Based Education (OBE)

Effective from Academic Year 2024-25

Semester- 1

Quantum Mechanics for nanostructures			
Course Code	**MNT101**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	50
Total Hours of Pedagogy	50	Total Marks	100
Credits	4	Exam Hours	3

Course Learning objectives:

- To provide knowledge of the foundations, techniques, and key result of quantum mechanics.
- To apply the quantum mechanics theory to important physical and nano systems
- To appreciate the applications of quantum mechanics in physics, engineering, and related fields

Module-1

Introduction : Wave-particle duality: Blackbody radiation, interaction of radiation with matter, photoelectric effect, Compton effect, wave-particle duality, De-Broglie's hypothesis, uncertainty relations, wave function, Schrodinger equation, Operators.

Module-2

Solutions of Schrodinger Equations

One-dimensional potential: Free electron in vacuum, electron in a potential well with infinite barriers, finite barriers and propagation of an electron above the potential well, Tunnelling: propagation of an electron in the region of a potential barrier. Three-dimensional potential: Electron in a rectangular potential well (quantum box) and spherically-symmetric potential well, Quantum harmonic oscillators, Phonons.

Module-3

Approximate methods of finding quantum states:

Stationary perturbation theory for a system with non-degenerate states and degenerate states. Non-stationary perturbation theory, quasi-classical approximation.

Module-4

Quantum states in atoms and molecules:

Quantum states in hydrogen atom, emission spectrum, spin of an electron. Many-electron atoms: wave function of a system of identical particles, hydrogen molecule.

Module-5

Quantization in nanostructures:

Number and density of quantum states, low-dimensional structures, Quantum states of an electron in low-dimensional structures, density of states for nanostructures, Double-quantum-dot structures (artificial molecules), electron in a periodic one-dimensional potential, one-dimensional superlattice of quantum dots, three-dimensional superlattice of quantum dots.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Two Unit Tests each of **25 Marks**
2. Two assignments each of **25 Marks**or **oneSkill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. Quantum Mechanics for Nanostructures, Vladimir V. Mitin, Dmitry I. Sementsov, Nizami Z. Vagidov. Cambridge University Press 2010.
2. Quantum Mechanics with applications to nanotechnology and information science. Yehuda B. Band, YshaiAvishai. Elsevier 2013.
3. Handbook of theoretical and computational Nanotechnology" eds. Michael Rieth and Wolfram Schommers, 2006.
4. Computational physics, R. C. Verma, K. C. Sharma & P. K. Ahluwalia.

Web links and Video Lectures (e-Resources):

- . Solutions of Schrodinger Equations: Prof. S. Lakshmi Bala, Department of Physics, IIT Madras: https://www.youtube.com/watch?v=t3A7WBLQjB4
- Approximate methods of finding quantum states: Prof. Saurabh Basu, IIT Guwahati: NPTEL Course Week 6 & 7: https://archive.nptel.ac.in/courses/115/103/115103104/
- Hydrogen atom wave functions: https://www.youtube.com/watch?v=V-RPM3e8Ws0
- Confinement and Quantization: Dr. Prathap Haridoss, IIT Madras: https://www.youtube.com/watch?v=rpj167L0JP8

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Comprehension of basic concepts will enable the students to apply quantum mechanics for solving problems in nanotechnology.	Understand
CO2	An ability to demonstrate a systematic knowledge of the computational modelling for Nanotechnology applications.	Apply

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5

Mapping of COS and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	x											
CO2	x	x	x	x	x							

Semester- 1

Thermodynamics and Kinetics for Nanoscience and Technology			
Course Code	**MNT102**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

- To Understand the fundamental Laws of Thermodynamics, and Chemical Kinetics of reactions.
- To Understand the application of statistical thermodynamics concepts for complex reaction and particularly for monodispersed nanoparticle synthesis

Module-1

Thermodynamic laws, Entropy, Statistical thermodynamics: micro-and macro-states. Unitary and multi-component systems, Gibbs phase rule, phase diagrams relevant to macro systems and for nanoscale materials formation, Phase transitions. General criterion for equilibrium-chemical potential and Gibbs free energy.

Module-2

Statistical Thermodynamics: Concepts of probability and Maxwell Boltzmann distribution. Different ensembles and partition functions. Thermodynamic functions using appropriate partition functions. Fermi-Dirac and Bose-Einstein statistics and statistical basis of entropy. Heat capacity of solids. Debye and Einstein models. Thermodynamic functions of ideal gases, translational, vibrational and rotational contributions at different levels of approximation. Application of statistical thermodynamics concepts to ortho para hydrogen internal rotation - Calculation of equilibrium constants.

Module-3

Phase Transformations: Fick's laws of diffusion, solution of Fick's second law and its applications, atomic model of diffusion, Temperature dependence of diffusion coefficient, Kirkendall effect. Thermodynamic considerations: Free energy of alloy phases and free energy-composition curves for binary systems.

Module-4

Nucleation and growth - energy considerations; heterogeneous nucleation, growth kinetics, overall transformation rates. Solidification: Nucleation and growth from liquid phase, stable interface freezing, cellular and dendrite growth, freezing of ingots, nucleation and grain size, segregation, directional solidification, growth of single crystals.

Module-5

Precipitation from solid solution: Homogeneous and heterogeneous nucleation of precipitates, the aging curve, mechanisms of age hardening, examples from Al-Cu and other alloy systems. Order-disorder Transformation: Examples of ordered structures, long and short-range order, detection of super lattices, influence of ordering on properties.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Two Unit Tests each of **25 Marks**
2. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. S. Glasstone, Thermodynamics for chemists, Affiliated East West Press, 1965.
2. B. C. McClelland, Statistical Thermodynamics, Chapman and Hall, 1973.
3. M. C. Gupta, Statistical Thermodynamics, Wiley Eastern Limited, 1993.
4. V. Raghavan, Solid State Phase Transformations, Prentice-Hall of India Pvt. Ltd. New Delhi, 1987.
5. D.A. Porter and K.E. Easterling, Transformations in metals and alloys, 2nd Edition, CRC Press, 1992.
6. N. D. Smith, Elementary Statistical Thermodynamics, Plenum Press, 1982.
7. J. Rajaram and J. C. Kuriacose, Thermodynamics for Students of Chemistry, Shobanlal Nagin Chand Co, 1986.
8. L. K. Nash, Elements of classical and statistical thermodynamics, Addison-Wesley, 1970.
9. G. M. Barrow, Physical Chemistry (V Edition), McGraw Hill international Series, 1988.
10. P. W. Atkins, Physical Chemistry, Sixth edition, Oxford University Press, 1990.

Web links and Video Lectures (e-Resources):

- Thermodynamics: classical to statistical: IIT Guwahati: https://www.youtube.com/watch?v=txOnRP5hwCE
- Phase Transformations: NPTEL, Lecture 13 onwards: https://archive.nptel.ac.in/courses/112/104/112104220/
- Nucleation and growth: IIT Roorkee: https://www.youtube.com/watch?v=lxNYAxr5lPc
  Precipitation from solid solution: Prof. R.N. Ghosh, IIT Kharagpur: https://www.youtube.com/watch?v=EtbJCAtX0Ps

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Explain fundamental Laws of Thermodynamics, and Chemical Kinetics of reactions.	Understand
CO2	Outline the application of statistical thermodynamics concepts for complex reaction and particularly for monodispersed nanoparticle synthesis.	Understand
CO3	Define phase transformation and crystallization of materials, and skill for nucleation and growth pattern of a nanoparticle.	Remember

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2

Mapping of COS and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	X	X								
CO2	X	X								
CO3	X	X								

Semester- I

MATERIALS SCIENCE AND PROPERTIES OF NANOMATERIALS			
Course Code	**MNT103**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

- To introduce various basic concepts of Nanoscience and Nanotechnology.
- To understand the relation between size and properties of Nanomaterials.
- To learn the importance of potential Nanomaterials for different application.

Module-1

Crystal structures

Crystal geometry: Crystal lattices, space lattices, basis and crystal structure, unit cell, lattice parameter of a unit cell - Seven crystal systems - Bravais lattices - Crystal directions and crystal planes (Miller indices) – Important parameters in crystal structures: Number of atoms per unit cell, Coordination number, Radius ratio, Packing factor - Some special crystal structures - Calculation of lattice constant – Symmetry elements and symmetry operations - Point groups - Crystallographic nomenclature - Imperfections/defects in crystalline solids.

Module-2

Bonding in Nanostructures

Atomic bonding in solids: Metallic, Ionic, Covalent, Co-ordination/dative bonds; Vander Waals interactions/Electrostatic interactions - Hydrogen bonding - hydrophobic interactions. Theories of bonding: VB theory, VSPR theory, Hybrization, MO theory - **Size effect of Nanomaterials:** Size, shape, density, melting point, wet ability, specific surface area, solid state phase transformation and band gap variation - Quantum confinement, Effect of strain on band gap in epitaxial quantum dots.

Module-3

Bonding in Nanostructures

Graphene – Fullerenes – Carbon nanotubes - Bonding in armchair, zigzag and chiral structures - n-m=3q rule – Inorganic nanotubes: Silica nanotubes, boron nitride nanotubes, Nanosheets of dichalcogenides - Nanowires of several metal oxides – Reactivity on Nanosurfaces: Functionalization of carbon nanotubes and Graphene.

Module-4

Electronic Properties

Classification of materials based on band structures - Brillouin zone – Effect of temperature on conductors – Intrinsic and extrinsic semiconductors - Electrical and electronic conductivity- Hall effect and its determination. **Dielectric Properties:** Kinds of dielectric materials, Dielectric constant and its determination – Piezoelectric, pyroelectric and ferroelectric materials. **Optical Properties:** Photoconductivity, Optical absorption and transmission - Photoluminescence, fluorescence and phosphorescence
– Electroluminescence – Band gap Engineering – Optical properties of semiconductor nanoparticles

Module-5

Mechanical behavior

Stress-strain, tensile strength, toughness, micro-hardness, wear resistance, corrosion resistance behaviors of nanomaterials. **Thermal properties:** Heat capacity, thermal conductivity and thermal expansion of nanomaterials. **Magnetic properties:** Fundamentals of magnetism - Different kinds of magnetic materials: dia, para, ferro, ferri and anti-ferromagnetic materials - Magnetic hysteresis – Superparamagnetism – Important properties in relation to Nano-magnetism.

Assessment Details (both CIE and SEE)

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Continuous Internal Evaluation:

1. Two Unit Tests each of **25 Marks**
2. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

TEXT BOOKS:

1. M.S.Vijaya,G.Rangarajan, Materials Science , Tata McGraw-Hill publishing company Ltd., New Dehli.
2. Theoretical Inorganic Chemistry – M.C. Day and I.Selbin, East –West Press, New Delhi, 1977.
3. Fundamental Properties of Nanostructured Materials, Ed. D. Fiorani (World Scientific, Singapore, 1994.
4. Nanoscience and Technology, V.S.Muralidharan and A.Sunramania, Ane Books Pvt. Ltd, India, 2009.
5. Nanostructured Materials and Nanotechnology – II, Eds. Sanjay Mathur and Mrityunjay Singh, Willey, 2008.
6. The Physics and Chemistry of Materials, Joel I.Gersten, F.W.Smith, S.R.Elliott, John Wiley &Sons,New York, 1998.
7. Properties of Materials, Robert E.Newnham,Oxford University Press, 2005.
8. Crystallography, Walter Borchardt-Ott, Springer, 1995.
9. Carbon Nanotubes Science and Applications, Edited by M.Meyappan, CRC Press, 2005.
10. Science of Fullerenes and Carbon Nanotubes, M.S.Dresselhaus, G.Dresselhaus,P.C.Eklund, Academic Press, 1996.
11. The Physics and Chemistry of Solids, S.R.Elliott, John Wiley & Sons, England, 1998.
12. Understanding Solids: The Science of Materials, Tilley, Richard J. D. John Wiley & Sons,2004V.Ragavan, Materials Science and Engg., Prentice-Hall of India(p) Ltd, New Delhi.
13. Nanostructured Materials, Edited by Carl C. Koch, Noyes Publications, New York, 2002.

Web links and Video Lectures (e-Resources):

- Introduction to Nanotechnology, Prof. A.K. Ganguli, IIT Delhi: https://www.youtube.com/watch?v=ebO38bbq0_4
- Overview of Nano structures and Nano materials: Dr. Anandh Subramaniam, IIT Kanpur: https://www.youtube.com/watch?v=YaoRYnGz5Aw
- Classification of nanomaterials: https://www.youtube.com/watch?v=pTktuQ_kpu8
- Metal and Metal Oxide Nanowires: Prof. A.K. Ganguli, IIT Delhi: https://www.youtube.com/watch?v=LhYg84HHcu4
- Electrical, Magnetic Properties: IIT Kanpur: https://www.youtube.com/watch?v=rEKyjwDLnTw , https://www.youtube.com/watch?v=xdWHlyizKbE
- Optical Properties: IIT Kanpur: https://www.youtube.com/watch?v=PL1ehCicN58

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Define the history, background and development of Nanoscience and Technology	Remember
CO2	Explain the structure-property relationships in nanomaterials as well as the concepts that are different from bulk counterpart.	Understand
CO3	Demonstrate a systematic knowledge of the range and breadth of application of nanomaterials.	Apply
CO4	Review critically the potential impact, in all classes of materials and nanostructure.	Evaluate

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5

Mapping of COS and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO9	PO11	PO12
CO1	x											
CO2	x											
CO3	x	x	x	x	x							
CO4	x	x	x	x	x							

Semester- I

Synthesis and Processing of Nanomaterials			
Course Code	**MNT104**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	03

Course Learning objectives:

1. To provide overview of various nanomaterial synthesis and processing techniques.
2. Introduce Principles and mechanism of different types of synthesis and processing techniques.
3. Learn to choose suitable synthesis process and condition to get desired nanostructures.

Module-1

Physical Methods:

Bottom-Up versus Top-Down; Top-down approach with examples. Ball milling synthesis, Arc discharge, RF-plasma, Plasma arch technique, Inert gas condensation, electric explosion of wires, Ion sputtering method, Laser pyrolysis, Molecular beam epitaxy and electrodeposition. Electro spinning, Physical Vapor Deposition (PVD) – Chemcial Vapour Deposition (CVD) - Atomic layer Deposition (ALD) – Self Assembly- LB (Langmuir-Blodgett) technique.

Module-2

Chemical methods:

Chemical precipitation methods- Coprecipitation, Arrested precipitation, Sol-gel method, Chemical reduction, Photochemical synthesis, Electrochemical synthesis, Microemulsions or Reverse Micelles, Sonochemical synthesis, Hydrothermal, Solvothermal, Supercritical fluid process.

Module-3

Combustion and Solution Methods:

Solution combustion process, spray pyrolysis method, flame spray pyrolysis, gas phase synthesis, gas condensation process, chemical vapour condensation. Fundamental aspects of VLS (Vapour-Liquid-Solid) and SLS (Solution-Liquid-Solid) processes – VLS growth of Nanowires – Control of the size of the nanowires – Precursors and catalysts – SLS growth – Stress induced recrystallization.

Module-4

Biological methods:

Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Natural and artificial synthesis of nanoparticles in microorganisms; Use of microorganisms for nanostructure formation, Role of plants in nanoparticle synthesis, synthesis of nanoparticles using proteins and DNA templates.

Module-5

Surface Modification of Nanoparticles

Introduction to Nanoparticles dispersion and aggregation behaviour, Surface interaction between nanoparticles, Difficulty in nanoparticle control based on DLVO theory. Effect of particle diameter and solid fraction on distance between the particle surface, Surface molecular level structure of Nanoparticles. Basic approach to control nanoparticle dispersion behaviour. Surface modification of inorganic nanoparticles by organic functional groups –Organic modification of Metal, Metal oxide nanoparticles, hybridization of inorganic nanoparticles with biomolecules. Surface modification of Carbon Nanostructures.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Two Unit Tests each of **25 Marks**
2. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

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Suggested Learning Resources:

Books

1.Guozhong Cao, "Nanostructures and Nanomaterials, synthesis, properties and applications", Imperial College Press, 2004

2.M.S. Ramachandra Rao, Shubra Singh, Nanoscience and Nanotechnology: fundamentals to Frontiers, Wiley 2013. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens

3. Hari Singh Nalwa - Encyclopedia of Nanotechnology.

4. Processing & properties of structural Naonmaterials by Leon L. Shaw (editor)

5. Chemistry of Nanomaterials : Synthesis, properties and applications by CNR Rao et.al.

6. Nanochemistry: A chemical approach to Nanomaterials Roayal Society of Chemistry, Ozin and Arsenault, Cambridge UK 2005,

7.Nanoparticles: From Theory to Applications, G.Schmidt, Wiley Weinheim 2004.

Web links and Video Lectures (e-Resources):

- Physical Methods: Dr. R. Nagarajan, Department of Chemical Engineering, IIT Madras: https://www.youtube.com/watch?v=WK9i1F4fOik
- Chemical Methods: IIT Kanpur: https://www.youtube.com/watch?v=evE08ycZfnM
- Combustion and Solution Methods: IIT Kanpur: https://www.youtube.com/watch?v=WHF4k-x2NLU
- Biological Methods: IIT Roorkee: https://www.youtube.com/watch?v=0md5JdAbj4U
- Surface Modification of Nanoparticles: Prof. Kaushik Pal, IIT Roorkee: https://www.youtube.com/watch?v=YsFw9SI3xV4

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Understand principles and mechanisms of various synthesis and processing techniques.	Understand
CO2	Demonstrate the knowledge to synthesize different nanomaterial choosing suitable method	Apply
CO3	Design desired nanostructure with size and morphology controlled to get desired property.	Create

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5

Mapping of COS and Pos

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	x											
CO2	x	x	x	x	x							
CO3	x	x	x	x	x							

Semester- I

Characterisation Techniques for Nanomaterials			
Course Code	**MNT105**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03

Course Learning objectives:

- The course aims at providing overview of various characterization techniques.
- Introduce working principles of different characterization techniques
- Analyze the data obtained from different techniques
- Evaluate size, structure, morphology and properties of nanomaterials.

Module-1

X-Ray based characterization

Principles and applications of X-ray diffraction, powder (polycrystalline) and single crystalline XRD techniques; Debye-Scherrer equation to treat line broadening and strain induced in nanoparticles and ultra-thin films. Basics of structure refinement (Reitveld). Rotating anode and synchrotron based X-ray diffraction for probing structure.X-ray photoelectron spectroscopy – basic principle, instrumentation, X-ray absorption techniques: XANES, EXAFS.

Module-2

Electron microscopy techniques

Introduction, Principles and applications of Electron beam, Electron beam interaction with matter. Scanning electron microscopy (SEM/FESEM), transmission electron microscopy (TEM/HRTEM), Electron-diffraction, SAED**.** Scanning Probe Microscopy: Principles and applications, Atomic Force Microscope, Scanning Tunnelling Microscope.

Module-3

Spectroscopic techniques

UV-VIS Spectrophotometers, IR/FTIR Spectrophotometers, Principles, operation and application for band gap measurements. Raman spectroscopy principles and applications. Optical microscope: Nanoparticle size measurement by Dynamic light scattering methods zeta potential.

Module-4

Magnetic characterization

Types of magnetic materials, Magnetic susceptibility, Curie-Weis plot for paramagnetic materials, Neel temperature, Curie temperature VSM and SQUID magnetometers – M vs H, M vs T, MH-loops.

Module-5

Electrical measurements

Cyclic Voltameter, Impedance Measurement, IV, AC and DC electric measurements, impedance spectral information.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. Minimum passing marks in SEE is 40% of the maximum marks of SEE. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 50% (50 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Two Unit Tests each of **25 Marks**
2. Two assignments each of **25 Marks** or **one Skill Development Activity of 50 marks** to attain the COs and POs

The sum of two tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. Characterization of Nanostructure materials by XZ.L.Wang
2. Instrumental Methods of Analysis, 7th edition- Willard, Merritt, Dean, Settle
3. *Scanning Probe Microscopy: Analytical Methods (NanoScience and Technology)-Roland Wiesendanger*

References:

1. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition Harold P. Klug, Leroy E. Alexander
2. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)- David B. Williams and C. Barry Carter

Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton.

Web links and Video Lectures (e-Resources):

- Material Characterization: IITM: https://www.youtube.com/watch?v=nSuHuaNT8kE
- Basics of X-ray emission from source, electron excitation and X-ray interaction: Dr. S. Sankaran, IIT Madras: https://www.youtube.com/watch?v=Nos_SQ2DpRw
- Introduction to scanning electron Microscopy: Dr. S. Sankaran, IIT Madras: https://www.youtube.com/watch?v=mC0rYNlMz9Q
- Fundamentals of Spectroscopy, Prof. Anirban Hazra, Prof. Sayan Bagchi, NCL Pune, IISER Pune: https://nptel.ac.in/courses/104106122
  Cyclic voltammetry, potentiodynamic polarization, pulse techniques, quartz crystal microbalance, scanning electrochemical microscopy: https://www.youtube.com/watch?v=SCEZoFmiUuk

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Identify the characterization technique suitable for their studies	
CO2	Analyze the data from various characterization techniques used to evaluate nanomaterial structure, size, morphology and properties.	
CO3	Understand the size and structure relationship and their suitability for an given engineering application.	

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5
6	Life-long learning	12

Mapping of COS and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	x											
CO2	x	x	x	x	x							x
CO3	x											

NANOMATERIALS SYNTHESIS AND CHARACTERISATION LAB			
Course Code	**MNTL106**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	04	SEE Marks	50
Credits	2	Exam Hours	3

Course objectives:

1. To learn the basic principles involved in nanoparticle synthesis.
2. To get hands on experience in synthesis of various nanoparticles.
3. To design desired size and morphology controlled nanostructures.
4. To learn to characterization of synthesized nanomaterials
5. Understand principles of various characterization techniques

Sl.NO	Experiments
1	Verification of Beer Lombard's Law
2	Synthesis of Au/Ag metal nanoparticles by Chemical reduction method, UV-Visible absorption studies of the Au/Ag metal nanoparticles
3	Synthesis of ZnO nanoparticles by hydrothermal method and Optical absorption spectra of the ZnO; Band gap estimation from the band edge
4	Synthesis of TiO_2 nanoparticles by Solvothermal method and Photocatalytic degradation property analysis
5	Synthesis of ceramic $BaTiO_3$ nanomaterial by combustion process and their crystal structure identification by X-ray diffraction studies
6	Synthesis of ceramic $SrTiO_3$ nanomaterial by Sol-Gel method and their Size Calculation Scherer's law by X-ray diffraction pattern
7	Surface functionalization or modification of Al_2O_3 metal oxide nanoparticles with organic reagents. Surface modification confirmation by dispersion in binary solvent (Organic-Aqueous) system
8	Synthesis of ZnS/MoS nanoparticles by microwave Solvothermal method followed by size and morphology analysis
9	Synthesis of Fe_2O_3/Mn_3O_4 nanoparticles by Co-precipitation method
10	Surface functionalization or modification of Fe_2O_3 metal oxide nanoparticles with organic reagents. Surface functional group identification by FTIR measurement
11	
12	

Course outcomes (Course Skill Set):

At the end of the course the student will be able to:

1. . Design the experiments to synthesize desired nanoparticles.
2. Prepare size and morphology controlled nanostructures.
3. Characterize the structural, optical and surface chemistry of the synthesized sample.
4. Relate the size and structure of materials to properties

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Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 50% of the maximum marks. A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each course. The student has to secure not less than 40% of maximum marks in the semester-end examination(SEE). In total of CIE and SEE student has to secure 50% maximum marks of the course.

Continuous Internal Evaluation (CIE):

CIE marks for the practical course is **50 Marks**.

The split-up of CIE marks for record/ journal and test are in the ratio **60:40**.

- Each experiment to be evaluated for conduction with an observation sheet and record write-up. Rubrics for the evaluation of the journal/write-up for hardware/software experiments designed by the faculty who is handling the laboratory session and is made known to students at the beginning of the practical session.
- Record should contain all the specified experiments in the syllabus and each experiment write-up will be evaluated for 10 marks.
- **Total marks scored by the students are scaled down to 30 marks** (60% of maximum marks).
- Weightage to be given for neatness and submission of record/write-up on time.
- Department shall conduct 01 tests for 100 marks, test shall be conducted after the 14th week of the semester.
- In test, test write-up, conduction of experiment, acceptable result, and procedural knowledge will carry a weightage of 60% and the rest 40% for viva-voce.
- The suitable rubrics can be designed to evaluate each student's performance and learning ability.
- **The test marks is scaled down to 20 marks** (40% of the maximum marks).

The Sum of **scaled-down** marks scored in the report write-up/journal and marks of test is the total CIE marks scored by the student.

Semester End Evaluation (SEE):

SEE marks for the practical course is 50 Marks.

SEE shall be conducted jointly by the two examiners of the same institute, examiners are appointed by the University.

All laboratory experiments are to be included for practical examination.

(Rubrics) Breakup of marks and the instructions printed on the cover page of the answer script to be strictly adhered to by the examiners. **OR** based on the course requirement evaluation rubrics shall be decided jointly by examiners.

Students can pick one question (experiment) from the questions lot prepared by the internal /external examiners jointly.

Evaluation of test write-up/ conduction procedure and result/viva will be conducted jointly by examiners.

General rubrics suggested for SEE are mentioned here, writeup-20%, Conduction procedure and result in -60%, Viva-voce 20% of maximum marks. SEE for practical shall be evaluated for 100 marks and scored marks shall be scaled down to 50 marks (however, based on course type, rubrics shall be decided by the examiners)

Change of experiment is allowed only once and 10% Marks allotted to the procedure part to be made zero.

The duration of SEE is 03 hours

Suggested Learning Resources:

1. Guozhong Cao, "Nanostructures and Nanomaterials, synthesis, properties and applications", Imperial College Press, 2004
2. M.S. Ramachandra Rao, Shubra Singh, Nanoscience and Nanotechnology: fundamentals to Frontiers, Wiley 2013.
3. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens.