DR. BABASAHEB AMBEDKAR MARATHWADA UNIVERSITY, AURANGABAD

NAAC Re-accredited 'A' Grade

Department of Nanotechnology

FACULTY OF SCIENCE & TECHNOLOGY

Two Years P.G. Programme in Nanotechnology

(M. Sc. Nanotechnology Semester I & II)

As Per National Education Policy-2020

(To be implemented from Academic Year 2023-24)

Course structure and Curriculum

(Outcome Based Credit System)

Subject : Nanotechnology

Effective from 2023-24

COURSE STRUCTURE AS PER THE GUIDELINES OF NEP-2020

Illustrative Credit distribution structure for Two Years M.Sc. Nanotechnology Postgraduate Programme with Multiple Entry and Exit options for discipline specific Course in Nanotechnology.

(A) PREFACE

Welcome to Department of Nanotechnology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad. The department is one of the most interdisciplinary and youngest departments on the university campus and also recognized. To the best of our knowledge, Dr. Babasaheb Ambedkar Marathwada University is the first university to start M. Sc. Nanotechnology course in Maharashtra and in particular in the Marathwada Region in order to provide opportunity to the youths of this region and to cope up with the growing interest in Nanotechnology from all the sector.

National Education policy 2020 has been intensely debated policies come into existence. In January, 2020 UGC has given the guideline for learning outcome based curriculum framework (LOCF) work towards more holistic experience for the students. while focusing not just on knowledge delivery in higher education but also on the application of knowledge through field and laboratory work and emphasis on application of knowledge to real life experiences, LOCF is student-centric education in the context of development of personal, social, professional and acquired knowledge requirements in their career and life building, which focuses on measuring student performance through outcomes. It includes the knowledge, skills and attitudes enhancement in the students.

The aspects of LOCF is all-round development of the students, skill acquisition outside chosen subjects and research were undetermined but NEP has changed all of these in one stroke. The prominent features of the NEP framework are: Student centric education, Flexibility in postgraduate programmes, multiple entry and exit points, Skill based & outcome base education, Credit based evaluation system, Academic bank credits.

It also focuses on evaluation of outcomes of the program by considering the knowledge, skill and behavior of a students after completion of two year program. The educational triangle of Teaching-Learning and Evaluation process is the unique features of the OBE approach. The curriculum practices such as Competency based curriculum, Tailor-made curriculum development, spades, curriculum principles, Blooms Taxonomy and further use of assessment methodologies like, Norm-reference testing and Criterion reference testing, etc is being practiced since decades. It is also interesting to know that, globally, different countries and universities adopts the curriculum development models /approaches such as, CDIO (Conceive-Design-Implement-Operate), Evidence based education systems approach, etc as the scientific and systematic approaches in curriculum design.

Maharashtra state government and the authorities of Dr. Babasaheb Ambedkar Marathwada University, Aurangabad has decided to implement National Education policies -2020 from the academic year 2023-24 for postgraduate program with outcome based education

As per guideline of OBE the department has prepared curriculum for Master of Science in Nanotechnology covered different interdisciplinary areas includes Chemistry, Physics, Life Sciences and other. The OBE syllabus will help to improve the quality and employability of the Post-graduates of the university department.

(B) VISION AND MISSION:

VISION

The Centre for Nanoscience and Nanotechnology is envisioned to impart high-quality education and conducting cutting-edge research in the emerging interdisciplinary areas of Nanoscience and Nanotechnology.

MISSION

- To excel in research and innovation for disseminating new knowledge and technological know-how.
- To create future industry-ready skilled manpower.
- Pedagogy development on cutting-edge technology and research.
- Creation of an industry-friendly research environment and state-of-the-art infrastructure.

(C) ADMISSION TO M.SC. NANOTECHNOLOGY PROGRAM

The admission to M.Sc. Nanotechnology program is conducted by the university by announcement of admission notification on www.bamu.ac.in and Centralized Admission process have been adopted for filling all seats as per intake capacity. For more information and detail kindly visit university website for all required details. Once the student is admitted to the department for the course, he/she will be promoted to next semester with full carryon; subject to the registration of student in every consecutive semester. Dropout student will be allowed to register for respective semester as and when the concerned courses are offered by the department, subject to the condition that his/her tenure should not exceed more than twice the duration of course from the date of first registration at parent department. The admission of concern student will be automatically get cancelled as per the university status of Dr. Babasaheb Ambedkar Marathwada University Aurangabad.

Intake Capacity MSc Nanotechnology: 20 seats

Course Fees Structure:

Please refer to the course prospectus of university for the course fees. Course Fees per semester for M.Sc. Nanotechnology and 20000/- (Non-Grant) per year.

Eligibility Criteria for Admission in Department Of Nanotechnology:

1) Candidate with bachelor's degree in any of science, engineering technology or pharmacy shall be held eligible for admission to the M.Sc. First Year (Semester-I) in Nanotechnology and specialization emerging hereafter.
2) With mathematics as one of the subject at least till H.S.C. i.e. 12th standard shall be held eligible for admission to M.Sc. in Nanotechnology.
3) With B.Sc./ B.E./ B.Tech./ B.Pharm./ degree examination of this university or any other university as equivalent there to with minimum 50% marks (45% for reserved category) shall be eligible for admission to M.Sc. Nanotechnology.
4) A candidate who has passed the bachelor's degree in the faculty of science ,

Engineering, Pharmacy or Technology subjects may be allowed to seek admission to the M.Sc. (Nanotechnology) course provided that he fulfill other conditions laid down in 0.848.

5) Nanotechnology being a fusion science, the subjects or sections within the subjects but not limited to the following list might be the part of the course work study for the M.Sc. examination. Physics, Chemistry, Biochemistry, Zoology, Botany, Modern Biology, Microbiology, Mathematics, Statistics, Biophysics, Applied Mathematics, Material Science, Geology, Modern industrial electronics and microwaves, Electronics, Environmental Science, Industrial Chemistry, Biotechnology, Computer Science ,All streams of engineering, All streams of technology, All streams / specialization in Medical and Pharmacy etc.

PROGRAME OBJECTIVES (POs) FOR MSC NANOTECHNOLGOY:

The program objectives for an MSc in Nanotechnology is aims to provide studies with a comprehensive understanding of the fundamental principles of nanoscience and phenomena that occur at the nanoscale, including quantum mechanics, nanomaterials, and nanotechnology. Following are the some potential program objectives that are typically framed by the department of Nanotechnology:

1. Acquire hands-on experience in using state-of-the-art experimental techniques and instruments for nanoscale characterization and fabrication **(Mastery of Experimental Techniques)**.

2. Gain a broad interdisciplinary knowledge base that incorporates concepts from physics, chemistry, biology, materials science, and engineering to address nanoscience-related challenges **(Interdisciplinary Knowledge)**.

3. Learn how to design and synthesize nanomaterials with specific properties and functionalities for various applications, such as electronics, medicine, energy, and environment **(Design and Fabrication of Nanomaterials)**.

4. Develop skills in analyzing and characterizing nanomaterials using advanced techniques like scanning probe microscopy, transmission electron microscopy, X-ray diffraction, spectroscopy, etc. **(Analysis Skills).**

5. Understand the safety considerations and ethical aspects associated with working at the nanoscale, including potential environmental and health impacts of nanomaterials **(Safety and Ethical Considerations)**.

6. Acquire knowledge of nanofabrication methods and nanodevice engineering to design and create novel nanostructures and devices **(Device Fabrication and Engineering)**.

7. Explore the potential applications of nanotechnology in diverse fields, including electronics, medicine, sensors, energy storage, and environmental remediation **(Problem Solving Abilities)**.

8. Research Skills: Develop research skills to conduct independent investigations, critically analyze scientific literature, and contribute to advancements in the field of nanoscience **(Research Skills)**.

9. Enhance communication and teamwork skills to effectively collaborate with multidisciplinary teams and present research findings to both technical and non-technical audiences **(Communication and Collaboration)**.

10. Foster an entrepreneurial mindset and explore the commercialization and industrial applications of nanotechnology **(Nanoscience Innovation and Entrepreneurship)**.

11. Cultivate a commitment to lifelong learning and staying updated with the latest developments in nanoscience and related fields **(Creative and Continuous Learning)**.

PROGRAME SPECIFIC OBJECTIVES (PSO) FOR MSC NANOTECHNOLGOY

PSO-1: Understand the principles and fundamentals of nanoscience and nanotechnology: Students will develop a comprehensive understanding of the theories and principles governing nanoscale phenomena, including quantum mechanics, nanomaterials, and nanofabrication techniques.

PSO-2: Design and synthesize nanomaterials: Students will be develop the ability to design, synthesize, and characterize various types of nanomaterials, such as nanoparticles, nanocomposites, and nanostructured materials, with specific properties for different applications.

PSO-3: Master advanced laboratory techniques and instrumentation: Students will acquire hands-on experience in operating sophisticated nanotechnology equipment and instruments, enabling students to perform experiments, analyze data, and characterize nanomaterials effectively.

PSO-4: **Explore interdisciplinary applications of nanotechnology:** Students will be effectively understand the diverse applications of nanotechnology across various disciplines, such as medicine, electronics, energy, and environmental sciences, and assess their potential impact on society.

PSO-5: Ethical and safety considerations in nanotechnology: Students will learn and recognize and address the ethical, social, and environmental implications of nanotechnology, while also understanding the importance of safety protocols when working with nanomaterials.

PSO-6: Engage in innovative research: Students get cultivated by the ability to conduct independent research in nanoscience and nanotechnology, including formulating research questions, designing experiments, and interpreting results effectively.

PSO-7: Effective communication of scientific findings: Enhance communication skills, both written and oral, to effectively present research findings, proposals, and scientific concepts to diverse audiences.

PSO-8: Collaborate and work in interdisciplinary teams: Students get cultivated with the ability to collaborate with professionals from different scientific backgrounds and work effectively in interdisciplinary teams to solve complex nanotechnology-related challenges.

SEMISTERWISE PROGRAME STRUCTURE
Semester-I

Course Type	Course Code	Course Name	Teaching Scheme (Hrs./ week)		Credits Assigned		
			Theory	**Practical**	**Theory**	**Practical**	**Total Credits**
Major Mandatory DSC	NTTC-500	Foundation of Nanoscience and Nanotechnology	2	-	2	-	8T
	NTTC -501	Chemistry of Nanomaterials	2	-	2	-	
	NTTC -502	Synthesis of Nanomaterials and Fabrication Techniques	2	-	2	-	
	NTTC -503	Scientific Commutation and Simulation in Nanoscience and Nanotechnology	2	-	2		
	NTLC-504	Laboratory –I	-	4	-	2	6L
	NTLC-505	Laboratory-II	-	4	-	2	
	NTLC-506	Laboratory-III	-	4	-	2	
DSE (Choose any two)	NTTE-507	Introduction to Bionanotechnolgy	2	-	2	-	4T
	NTTE -508	Materials and Methods of Nanocoatings	2	-	2	-	
	NTTE -509	Societal Impacts of Nanotechnology	2	-	2	-	
	NTTE -510	Introduction to Nanoelectronics and Quantum Devices	2	-	2	-	
RM	NTRM-511	Research Methodology-I	2	-	2	-	4T
	NTRM-512	Research Methodology-II	2	-	2	-	
Total			**16**	**12**	**16**	**06**	**22**

***- a)** Choice of DSE courses for offline mode is to the students subject to prior reporting of minimum ten students. b) Among the Four courses from DSE, one DSE is compulsory for offline mode and one among the remaining three for online (MOOC, NPTEL) mode. c) If online course for DSE is not available, students should choose two courses for offline mode.

<u>Course Code Nomenclature</u>:

DSC-Discipline Specific Core, **DSE-** Discipline Specific Elective, **T**-Theory**, L-** Laboratory course, **NTTC-**Nanotechnology Theory Core, **NTLC-**Nanotechnology Laboratory Core, **NTTE-**Nanotechnology Theory Elective, **NTRM-** Nanotechnology Research Methodology, **NTOJT-** Nanotechnology on the Job Training, **NTFP-**Nanotechnology Field Project

Semester-II

Course Type	Course Code	Course Name	Teaching Scheme (Hrs./ week)		Credits Assigned		
			Theory	Practical	Theory	Practical	Total Credits
Major Mandatory DSC	NTTC-550	Nanomaterials Based Devices: MEMS and NEMS	2	-	2	-	8T
	NTTC -551	Physics of Nanomaterials	2	-	2	-	
	NTTC -552	Characterization Techniques for Nanomaterials	2	-	2	-	
	NTTC -553	Carbon Nanomaterials: Synthesis, Functionalization and Applications	2	-	2		
	NTLC-554	Laboratory –IV	-	4	-	2	6L
	NTLC-555	Laboratory-V	-	4	-	2	
	NTLC-556	Laboratory-VI	-	4	-	2	
DSE* (Choose any two)	NTTE-557	Advancement to Bionanotechnolgy	2	-	2	-	4T
	NTTE -558	Theoretical Studies in Nanoscience: Scientific Computation and Simulation	2	-	2	-	
	NTTE -559	Nanocomposites: Fabrication, Properties and Applications	2	-	2	-	
	NTTE -560	Nanotechnology in Energy and Environment	2	-	2	-	
OJT	NTOJT-561	On the Job Training	-	4	-	4	4L
	NTFP-562	Field Project	-				
Total			**12**	**20**	**12**	**10**	**22**

***- a)** Choice of DSE courses for offline mode is to the students subject to prior reporting of minimum ten students. b) Among the Four courses from DSE, one DSE is compulsory for offline mode and one among the remaining three for online (MOOC, NPTEL) mode. c) If online course for DSE is not available, students should choose two courses for offline mode.

<u>Course Code Nomenclature</u>:

DSC-Discipline Specific Core, **DSE-** Discipline Specific Elective, **T**-Theory**, L**- Laboratory course, **NTTC-** Nanotechnology Theory Core, **NTLC-**Nanotechnology Laboratory Core, **NTTE-**Nanotechnology Theory Elective, **NTRM-** Nanotechnology Research Methodology, **NTOJT-** Nanotechnology on the Job Training, **NTFP-** Nanotechnology Field Project

	Semester: I	
Course Name: Foundation of Nanoscience and Nanotechnology		**Course Code: NTTC-500**
Course type: DSC		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

To provide the students with basic knowledge of nanoscience and nanotechnology, so that they would be able to understand and distinguish between variety of nanomaterials based on their structure and properties and understand the theoretical background.

Prerequisites:

A solid understanding of fundamental science subjects like physics, chemistry, and biology is essential. Nanoscience and nanotechnology draw heavily from principles in these disciplines.
Familiarity with concepts in chemistry, including atomic structure, chemical bonding, and molecular interactions, is crucial for understanding the synthesis and properties of nanomaterials.

Learning Outcomes (LO):

- Students will get to know the emergence and fundamental concepts of nanoscience and nanotechnology.
- Students will get to know the quantum mechanics that lay the foundation of nanoscience and nanotechnology.
- Students will get to know the basic concepts of quantum statistics and its application to many electron systems and phonon phenomena.

Course Outline:

Unit 1: Foundation to Nanoscience: Importance of nanotechnology, history of nanotechnology, inter molecular forces responsible for assembly and stability, classification based on the dimensionality, nanoparticles-nanoclusters-nanotubes-nanowires, influence of nanostructuring on mechanical, Mie theory and origin of optical properties, electronic, magnetic and chemical properties and their origin. Failure of classical mechanics, brief discussion of general ideas such as wave particle duality, uncertainty principle, superposition principle, quantum mechanics of electrons, postulates of quantum mechanics, Schrodinger approach, Dirac's bra-ket notation, operators & operator algebra, Eigen values and eigen functions, free and confined electrons - time dependent and time independent Schrödinger's equation, solutions of Schrödinger equation for 1-D and 3-D square wells and potential barriers, barrier penetration, tunnelling effect, particle in a box, H-atom problem, time independent and time dependent perturbation theory for non-degenerate and degenerate energy levels.
Applications of barrier penetration - STM. Tunnelling in field emission guns, solution of Schrödinger equation for various dimensional nanomaterials, quantum confinement. Electron wave functions in semiconductor nanocrystals, Brus relation. Changes of Fermi levels in nanomaterials as a consequence of quantization.

Unit 2: Concept of Quantum Computation: Quantum Qubits, introduction to nuclear spin, quantum devices, single electron devices. Many electron phenomena- statistical description of a physical system, phase space, microstates and macrostates, density of states, classical and quantum statistics, ideal gas and Gibbs paradox. Theory of ensembles - canonical, micro-canonical and grand canonical ensemble, the micro-canonical ensemble theory and its application to ideal gas, the canonical ensemble and its thermodynamics, partition function, energy fluctuations, equipartition, harmonic oscillator as canonical ensemble, grand canonical ensemble and significance of statistical quantities.

Unit 3: Concept of Quantum Computation: Quantum statistics- quantum ensemble, statistics of occupation, thermodynamical behavior of ideal Bose gas, Bose-Einstein condensation, discussion of a gas of phonons, thermodynamics of a Fermi gas, free electron gas and Pauli paramagnetism.

Text Books and References:

1. 'Concepts of Modern Physics' by Arthur Beiser, Shobhit Mahajan, and S Rai Choudhury, Sixth edition, McGraw-Hill.
2. 'Quantum Mechanics' by Leonard I. Schiff, Jayendra Bandhyopadhyay, Fourth edition Tata Mcgraw Hill.
3. 'Quantum Mechanics: Theory and Applications' by S. Lokanathan and A. Ghatak, Sixth edition, Laxmi Publications Pvt Ltd (1 January 2022); Laxmi Publications Pvt Ltd
4. 'A textbook of Nanoscience and Nanotechnology' by Pradeep T. Tata McGraw – Hill education private ltd. 2017.
5. 'Introduction to Quantum Mechanics' by David J. Griffiths, Second edition, Pearson, 2015.
6. 'Introductory Quantum Mechanics' by Richard L. Liboff, Fourth edition, Pearson, 2003.
7. 'An Introduction to Thermodynamics and Statistical Mechanics' by Keith Stowe Second edition, Cambridge University, Newyork, 2007.
8. 'Statistical Physics' by Claudine Herman, Springer, New York, 2005.
9. 'Introduction to Solid State Physics' by Kittel. C, Eight edition, Wiley India Pvt. Ltd., 2012.
10. 'Nanomaterials Chemistry' by Rao. C. N. R., Muller. A, Cheetham A. K. Wiley-VCH, 2007.

	Semester: I	
Course Name: Chemistry of Nanomaterials		**Course Code: NTTC-501**
Course type: DSC		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

To provide the students with the chemical foundation of nanoscience and the concepts of solid state chemistry, colloidal & surface chemistry, so that they would be able to understand and distinguish between variety of nanomaterials based on their chemical structure and properties and understand the chemistry behind the formation of nanomaterials.

Prerequisites:

A strong foundation in general chemistry is typically required to understand the fundamental concepts of chemistry, including atomic structure, chemical bonding, stoichiometry, and chemical reactions. Depending on the course's focus, a background in materials science can be valuable for understanding the properties and behavior of nanomaterials.

Learning Outcomes (LO):

- Students will get to know the various aspects of chemical bond formation useful for nanomaterials.
- Students will get to know the concept of adsorption and absorption.
- Students will get to know the wetting behaviour of surfaces and the concept of surface energy.
- Students will get to know the crystal structure and types of crystal defects.
- Students will get to know the underlying phenomena and origin of stability and instability in colloidal systems.

Course Outline:

Unit 1: Foundation to Chemical Structure: Electronegativity, variation of electronegativity, polarities of bonds and molecules, dipole moments. Percentage of ionic character from dipole moment and electronegativity difference. Valence bond (VB) theory, resonance structures, bond angles and shapes of molecules and ions, criterion of bond strength and bond length. Molecular orbital (MO) theory of bonding - bonding in homo-nuclear and hetero-nuclear molecules. Comparison of VB and MO theories. Essential molecular orbital theory and molecular structure concepts of organic semiconductors and organic nanoparticles, synthesis, examples of organic semiconductor materials and devices, physical properties and spectroscopy. Bond formation and surface functionalization of nanomaterials - assembly of nanomaterials. Introduction to macromolecules and self-assembly. Introduction to surface techniques. Crystalline and amorphous solids, isotropy and anisotropy, crystal systems. Defects in crystals - intrinsic and extrinsic defects, point defects, line and plane defects, vacancies - Schottky and Frankel defects, color centres and other defects in non-stoichiometric crystals.

Unit 2: Surface Properties: Adsorption and absorption, adsorption isotherms - adsorption and desorption kinetics. Wetting behavior of surfaces - concept of contact angle and measurement techniques. Introduction to thermodynamics - enthalpy and entropy, introduction to the concept of chemical potential, surface energy and surface tension, its consequences in nanomaterials, homogenous and heterogeneous nucleation.

Unit 3: Chemistry of Colloidal Solutions: Classification of colloids and purification of colloidal solution (dialysis, electro-dialysis, ultrafiltration). Chemistry of surfaces - curvature and neighboring charge effects on chemical reactivity and equilibria (pKa's, redox potentials), electrical double layer and zeta potential. Instability in colloidal systems- nucleation and growth, Ostwald ripening-homogeneous vs. heterogeneous nucleation. Stability of colloidal systems and surface functionalization. Anisotropic growth and shape control-catalysed (seeded) growth - effect of capping agents on growth kinetics.

Text Books and References:

1. ‘A textbook of Nanoscience and Nanotechnology’ by Pradeep T. Tata McGraw – Hill education private ltd, 2012.
2. ‘Physical Chemistry’ by Peter Atkins, Julio de Paula, and James Keeler Eleventh edition, Oxford Press.
3. ‘Introduction to Modern Colloid Science’ by Robert J. Hunter, Oxford University Press.
4. ‘Thermodynamics and Statistical Mechanics’ Volume 10, by John M. Seddon, J. D. Gale., RSC publishing
5. ‘Nanomaterials Chemistry’ by Rao. C. N. R., Muller. A, Cheetham A. K. Wiley-VCH, 2007.

	Semester: I	
Course Name: Synthesis of Nanomaterials and Fabrication Techniques		**Course Code: NTTC-502**
Course type: DSC		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

To provide the students with the knowledge of synthesis and fabrication techniques of nanomaterials, so that they would be able to apply it in industrial process for the synthesis of nanomaterials.

Prerequisites:

A fundamental understanding of chemistry is essential as nanomaterial synthesis often involves chemical reactions, stoichiometry, and reaction kinetics. Knowledge of atomic structure, chemical bonding, and basic concepts of inorganic and organic chemistry will be beneficial.
Familiarity with standard laboratory techniques, safety protocols, and hands-on experience with chemical and materials synthesis will be advantageous, as the course may involve practical work in a laboratory setting.
A general understanding of nanotechnology and nanoscale phenomena can provide students with insights into the unique properties and behavior of nanomaterials.

Learning Outcomes (LO):

- Students will get to know the various types of nanomaterials.
- Students will get to know the techniques of synthesis of nanomaterials.
- Students will get to know the various methods of synthesis of nanomaterials.
- Students will get to know the stabilization and purification methods for nanomaterials.
- Students will get to know the requirements and become familiar with clean room environment.

Course Outline:

Unit 1: Classifications and types of nanomaterials: 1D, 2D, 3D-nanomaterials, Concept of bulk versus nanomaterials and dependence of properties on size. Fabrication techniques for nanomaterials: topdown and bottom-up approaches. Nano synthesis techniques based on liquid and vapour phase as the starting material - study of wet chemical methods like sol-gel method, hydrothermal, micro emulsion technique, chemical reduction, decomposition of organometallic precursors and chemical vapour deposition, metallo-organic chemical vapour deposition, chemical synthesis and rapid solidification, electro and electroless deposition. Synthesis using templates, microwave and ultrasound assisted synthesis, photolysis, and radiolysis. Surfactant behaviour - micelles, selfassembled mono layers (SAM's), Langmuir-Blodget (LB) films.

Unit 2: Physical Methods for Synthesis: Working principles of chemical & physical vapour deposition, RF sputtering, arc-discharge, laser ablation, thermal evaporation, e-beam techniques, MBE, MOCVD. Mechanical attrition, high energy ball milling, mechano-chemical pulverization, mechanism of grain size reduction. Introduction to optical, electron beam, and X-ray lithography systems and processes. Design methodology, overview of sub 100 nm scaling challenges and sub-wavelength optical lithography, back-end-of-line challenges (metallization), front-end-of-line challenges (transistors) - process control and reliability of lithographic issues. Wet etching and dry etching, etch resists. New breed of circuit and physical design -modelling challenges.
Unit 3: Fabrication of Nanodevices: micro/nano - electronic devices, interconnect materials, opportunities and limitations. Focused ion beam lithography, working principal, instrumentation and uses in nanostructure, preparation of TEM lamella. Nanoimprint lithography working principal, instrumentation and uses. Scanning near field lithography, scanning probe based lithography methods - AFM and STM lithography, dip pen lithography.

Text Books and References:

1. ‘Encyclopedia of Nanotechnology’ Vol 1-10, by Hari Singh Nalwa, American Scientific Publishers; 1st edition (1 January 2004)
2. ‘Nanotechnology: Importance and Applications’ by M.H. Fulekar, IK International 2010.
3. ‘Nanomaterials Chemistry’ by Rao C. N. R., A. Muller, A. K. Cheetham, Wiley VCH, 2007.
4. ‘Nanomaterials and Nanochemistry’ by Brechignac C. P. Houdy, M. Lahmani, Springer publication, 15 Oct 2010.
5. ‘Nanoscale Materials in Chemistry’ by Kenneth J. Klabunde, Wiley Interscience Publications 2001.
6. ‘Nanochemistry’ by Kenneth J. Klabunde, Sergeev G. B., Elsevier publication 2006.
7. ‘Nanostructures and Nanomaterials, Synthesis, Properties and Applications’ by Guozhong Cao, Imperial College Press 2004.
8. ‘Nanomaterials – Handbook’ by Yury Gogotsi, CRC Press, Taylor & Francis group, 2006.

	Semester: I	
Course Name: Scientific Computation And Simulation In Nanoscience & Nanotechnology		Course Code: NTTC-503
Course type: DSC		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

To provide the students with basic knowledge of simulation and theoretical studies in nanoscience and nanotechnology.

Prerequisites:

A solid understanding of physics and chemistry is essential for comprehending the fundamental concepts in nanoscience and nanotechnology.
Familiarity with nanoscience principles, including nanoscale phenomena, nanomaterial synthesis, and characterization techniques, will provide valuable context for the simulations.

Learning Outcomes (LO):

- Students will get to know the C++ programming.
- Students will get to know the use of computation techniques like Origin, DOS, UNIX and Windows.
- Students will get to know and perform various numerical methods of matrices, error analysis, interpolation, extrapolation and other numerical methods.
- Students will get to know the simulation and analysis techniques.

Course Outline:

Unit 1: Tools - Practical approach to learning operating systems (DOS, UNIX, Windows) and Graphical packages (Origin).

Programming - C ++ programming, character set, variables, constants, data types and their declarations, relational operators, logical operators, arithmetical operations, built in functions, input output statements, functions, subroutine, array handling.

Unit 2: Numerical Methods I - Matrices, solution of system of linear equations, direct methods, error analysis, curve fitting, iterative methods, Numerical differentiation and integration methods, quadrature formula, numerical methods for ordinary equations, stability and convergence.

Unit 3: Numerical methods II - Interpolation, extrapolation, Numerical solution of partial differential equation, initial value problems. Random numbers - Monte-carlo integral methods, importance sampling, fast Fourier transform. Physical simulations - N body methods and particle simulations, Verlet algorithm, molecular dynamics and monte-carlo methods. Simulation of small system and Ab initio methods, density functional theory.

Text Books and References:

1. 'Numerical Methods for Scientific and Engineering Computation' by M. K. Jain, S. R. K. Iyengar and R. K. Jain, Sixth edition, New Age International Pvt Ltd Publishers.
2. 'Handbook of Theoretical and Computational Nanotechnology' by Eds. Michael Rieth and Wolfram Schommers, First edition, American Scientific Publishers, 2006.
3. 'Introductory Computational Physics' by Andi Klein and Alexander Godunov, Cambridge University Press.

	Semester: I	
Course Name: Laboratory Course –I, II and III		Course Code: NTLC-504, 505,506
Course type: DSC		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

To provide the students with basic knowledge of simulation and theoretical studies in nanoscience and nanotechnology.

Prerequisites:

A strong foundation in general chemistry is crucial since nanoscience and nanotechnology involve understanding chemical reactions and materials at the atomic and molecular level.
Familiarity with the basic principles of materials science and engineering will be beneficial, as nanotechnology often involves manipulating and characterizing materials at the nanoscale.

Learning Outcomes (LO):

- Students will get to know basic universal safety standards and practices in laboratories.
- Students will get to some of the chemical synthesis of nanomaterials.
- Students will get to know some of the characterization methods for nanomaterials.
- Students will get to know 2D surfaces, oxide nanomaterials, and metal nanoparticles

Course Outline:
List of open ended experiments:

NTLC-504:
1. Synthesis of Nanomaterials by Chemical Bath Deposition
2. Synthesis of Nanomaterials by Successive Ionic Layer Adsorption and Reaction
3. Synthesis of Silver Nanoparticles using Chemical Reduction Method
4. Characterization of Nanoparticle Size Distribution using Dynamic Light Scattering (DLS)
5. To determine the crystal structure, grain size and lattice parameters using XRD data of a given sample.
6. Study of Nanomaterials' Optical Properties using UV-Vis Spectroscopy

NTLC-505:
1. Surface functionalization and characterization of 2D surfaces.
2. Synthesis of metal nanomaterials, characterization, and data analysis.
3. Preparation of oxide nanomaterials, characterization and data analysis.
4. Synthesis of Gold Nanoparticles using Green Chemistry Approach
5. Synthesis of Titanium Dioxide Nanoparticles using Sol-Gel Technique
6. Preparation and Characterization of Nanoparticles for Electrocatalytic Hydrogen generation

NTLC-506:
1. Fabrication of Zinc Oxide Nanorods via Hydrothermal Synthesis
2. Preparation of Iron Oxide Nanoparticles through Co-precipitation Method
3. Preparation of Polymer Nanocomposites via In-situ Polymerization
4. Deposition of Thin Films using Sputter Coating Unit
5. Synthesis of graphene by Hummer’s method.

	Semester: I	
Course Name: Introduction to Bionanotechnology		**Course Code: NTTE-507**
Course type: DSE		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

To provide the students with the knowledge of application of nanotechnology in biotechnology, so that they would be able to apply it in industrial applications of biological process.

Prerequisites:

A foundational understanding of biology is essential as bionanotechnology involves the integration of biological principles with nanotechnology. Topics such as cell biology, molecular biology, genetics, and biochemistry may be relevant.
Knowledge of basic chemistry concepts is crucial, as it forms the basis of understanding various nanotechnology applications and biomolecular interactions.
Knowledge of materials science can aid in understanding the properties and behaviors of nanomaterials.

Learning Outcomes (LO):

- Students will get to know the fundamentals nanobiotechnology.
- Students will get to know the international standards and practices of nanobiotechnology.
- Students will get to know DNA, proteins, amino acids, drug delivery, biomedicine etc.
- Students will get to know the functional principles of bionanotechnology.
- Students will get to know the applications and possibilities of biomaterials to enhance the quality of life.
- Students will get to know the various classes of biomaterials and process like enzyme kinetics.
- Students will get to know the characteristics of the biomaterials for technology development.

Course Outline:

Unit 1: Introduction to microbes and cell biology. Preparation of bacterial culture and study of its growth, isolation, preservation. Introduction to bio-conjugation, interaction of biomolecules with nanoparticles, surface functionalization/modification of nanoparticles, nanoparticles in biological labelling and cellular imaging: science of nanoparticles functionalization. Introduction to classes of materials used in medical applications: metals, polymers, ceramics, biodegradable materials, coatings, medical fibers, non-fouling surfaces. Enzymes- enzyme kinetics and industrial applications of enzymes. In vitro and in vivo assessment of tissue compatibility and imaging methods. Testing methods and interactions of nanomaterials with biomolecules.
Unit 1: Polymers in drug delivery: Introduction to polymeric drug delivery systems, targeted drug delivery. Passive or active targeting, targeting tumor cells, polymer-protein conjugates, polymer drug-conjugates. Degradation of materials in the biological environment: Effects of the biological environment on metals, polymers and ceramics. Relevant international standards: ISO, FDA and ASTM. Cytotoxicity, systemic effects, genotoxicity, carcinogenicity, reproductive toxicity, sensitization & irritation, tissue compatability and inflammatory response, evaluation of host response.

Unit 2: Bio-mineralization: Bioactive glasses and glass-ceramics, calcium phosphate ceramics, calcium phosphate coatings, calcium phosphates, clinical applications of hydroxyapatite. Dental materials-introduction to dental materials polymers, ceramics and metals, applications of dental materials, physio-chemical, mechanical, toxicological and in vitro clinical performance of dental materials and implants.
Pharmacokinetics-application of hydrogels in controlled drug delivery systems. Smart biomaterials-stimuli responsive polymers (pH, temperature, light, magnetic and biomolecules) and their applications as biomaterials. Stimuli responsive hydrogels.

Unit 2: Bio-nanomaterials: Nanogels and microgels- preparation methods, characterization and applications. Self-assembled materials-3D bio-printing. Bio inspired nanomaterials - super hydrophobic materials such as lotus leaf structure, bioinspired superglues, ultra-hard materials, organic and inorganic natural nanomaterials- bio-mineralization, natural fibers, nanomaterials derived from cells.

Text Books and References:

1. ‘Biomaterials Science: An Introduction to Materials in Medicine’ by B. Ratner, A. Hoffman, F. Schoen, J Lemons, 3rd edition, Academic Press, 31 Dec 2012.
2. ‘Polymeric Biomaterials’ by S. Dumitriu and Marcel Dekker, second volume, 3rd edition 2002, CRC Press.
3. ‘Nanotechnology and Tissue Engineering’ by C. T. Laurencin, L. S. Nair, The Scaffol, CRC Press, First edition, 2008.
4. ‘Biomaterials: A Nano Approach’ by S. Ramakrishna, T. S. Sampath Kumar, CRC press, 2010.
5. ‘Smart Polymers: Applications in Biotechnology and Biomedicine’ by I. Galaev, Bo Mattiasson, 2nd Edition, CRC Press, 2007.
6. ‘Smart Polymer Materials for Biomedical Applications (Materials Science and Technologies)’ by S. Li, A. Tiwari, M. Prabaharan and S. Aryal, Nova Science Publishers Inc, 2010.
7. ‘Nanotechnology in Drug Delivery’ by M. De Villiers, P Aramwit and G S. Kwon, Volume X, Springer, 2009. 8. ‘Nano Characterization’ by A. Kirkland and J. Hutchison, Volume 37, Second edition, RSC publishers, 2007.

	Semester: I	
Course Name: Materials and Methods of Nanocoatings		**Course Code: NTTE-508**
Course type: DSE		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

To provide the students with the knowledge of coating science and technology of nanomaterials with a broad perspective covering the theoretical part, raw materials, coating formulation, coating production, coating application, coating testing and challenges of the coatings industry.

Prerequisites:

Familiarity with basic concepts in materials science or engineering, such as crystal structures, phases, mechanical properties, and thermodynamics, will be advantageous.
Since nanocoatings often involve experimental work, familiarity with laboratory techniques and safety protocols is crucial. Prior exposure to conventional coatings technology can provide a good foundation for understanding the challenges and improvements that nanocoatings offer.

Learning Outcomes (LO):

- Students will get to know the surface engineering techniques and identify the appropriate manufacturing processes for nanocoatings.
- Students will get to know the difference between traditional coating and nanocoating techniques.
- Students will get to know the various techniques of nanocoatings.
- Students will get to know the materials and mechanism of nanocoatings.
- Students will get to know the various devices based on nanocoatings.

Course Outline:

Unit 1: Introduction nanomaterials for coatings: nanostructuring methods - cathodic arc evaporation, plasma enhanced chemical vapor deposition, pulsed current in nanocoatings. Characterization of coatings- hardness, adherence and internal stresses, mechanical behaviour and machining performances. Nanostructures by ion irradiation, implantation, sputtering, cleaning, roughening of surface for improving the adhesion of coatings, ion beam assisted deposition (IBAD) and ion beam deposition (IBD) of monoatomic ions or clusters, microencapsulation, decorative and golden PVD coatings, concept of color, reactive gas flow, influence of oxygen in the layers. Determining internal stresses by radius of curvature measurements (Stoney's method), determining residual stresses using x-ray diffraction, high temperature oxidation resistance of nanocomposite coatings. Case studies and modern day examples.

Unit 2: Introduction surface engineering: Conventional and modern deposition methods, Transparent polymer nanocomposites, silane & silica coating, nanocomposite processing- melt blending, in situ synthesis. Optical, thermomechanical and mechanical properties of the nano coatings. Polymer processing rheology, compounding and processing of plastics and rubbers, fibre spinning and manufacturing processes.
Unit 2: Ceramic processing: pressing, CIP, HIP, slurry processing, slip casting, pressure casting, tape casting, gel casting, rapid prototyping, sol-gel processing, thermal and plasma spraying, thick and thin film coatings. Processing of metallic materials- casting processes, casting design and defects. Fundamentals of deformation processing, hot and cold working, metal joining process, design aspects, Materials selection and design, weighting factors, materials performance index. Design of engineering structures. Modern metallic, ceramic, polymeric and biomaterials devices and components by nanocoatings.

Text Books and References:

1. ‘Nanomaterials and Surface Engineering’ by Jamal Takadoum (Ed) Publisher: ISTE Ltd and John Wiley & Sons, Inc. 2009.
2. ‘Ceramic Materials: Processes, Properties and Applications’ by P. Boch, J-C. Nièpce, Wiley-ISTE, 2007.
3. ‘Electrospun Nanofibres and Their Applications’ by J-H. He, Smithers Rapra Technology 2008.
4. ‘Principles of Polymer Processing’ by Z. Tadmor, C.G. Gogos Wiley International, 2nd ed. 2006.
5. ‘Polymer Processing Fundamentals’ by T. A. Osswald, Carl Hanser Verlag GmbH & Co November 1, 1998. 6. ‘Elements of Metallurgy and Engineering Alloys’ by F. C. Campbell, ASM International 2008.
7. ‘Materials and Processes in Manufacturing’ E. Degarmo, by J. T. Black and R. A. Kohser Wiley, June 2017, 12th ed.
8. ‘Manufacturing Engineering and Technology’ by S. Kalpakjian, S.R. Schmid Pearson, 7th ed. 2018.

	Semester: I	
Course Name: Societal Impacts of Nanotechnology		**Course Code: NTTE-509**
Course type: DSE		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

To provide the students with the knowledge of socio economic impact of nanotechnology and to handle the consequences effectively.

Prerequisites:

An understanding of fundamental concepts in physics, chemistry, and biology is essential to grasp the underlying principles of nanotechnology and its societal implications.
Familiarity with the basics of nanotechnology, including nanomaterials, nanodevices, and nanoscale phenomena, will provide a solid foundation for exploring its societal impacts.
Strong critical thinking skills and the ability to articulate ideas effectively are important for engaging in discussions and debates about the societal implications of nanotechnology.

Learning Outcomes (LO):

- Students will have awareness about socio economic impact of nanotechnology and to handle the consequences effectively.
- Students will get to know about various social impacts of nanotechnology trend and research.
- Students will equip with ethical issues and public opinion effectively.
- Students will understand the professional and ethical responsibility.

Course Outline:

Unit 1: Patentability requirements: Infringement issues. Nanotech patents in India and abroad-copyright requirements-nanotech creation as artist works. Delegation of power of agencies – national and international examples of regulation of nanotechnology environmental regulations - regulation of exports - political and judicial control over agency action.

Unit 2: Economic impacts and commercialization: - introduction, socio-economic impact. Initial results and managing the nanotechnology revolution- Malcolm Baldrige national quality criteria. The emerging of nano economy-key drivers, challenges and opportunities. Transcending Moore’s law with molecular electronics and nanotechnology. Navigating nanotechnology - nanotechnology based surveillance and society. Methodological issues and innovations for social research. Societal implications- individual perspectives and social trends.

Unit 2: Ethics and law: ethical issues in nanoscience and nanotechnology. Reflections and suggestions-ethics and nanotechnology. Survey for law in a new frontier- exploration of patent matters associated with nanotechnology. The ethics of ethics -negotiations over quality of life in the nanotechnology initiative.
Governance-problems of governance of nanotechnology. Societal implications of emerging science and technologies. A research agenda for science and technology studies (STS)- institutional impacts of government science initiatives and policies - nanotechnology for national security. Security surveillanceimpact of artificial intelligence (AI) based surveillances on individuals and society.

Text Books and References:

1. ‘Nanotechnology: Societal Implications II-Individual Perspectives’ by Mihail. C, Roco and William Sims Bainbridge Springer, 2007.

2. ‘Nanotechnology: Risk, Ethics and Law’ by Geoffrey Hunt and Michael. D Mehta, Routledge; 1st edition (July 1, 2006).
3. ‘Nanotechnology: Global Strategies, Industry Trends and Applications’ by Jurgen Schulte John Wiley & Sons Ltd. 2005.
4. ‘Environmental Nanotechnology Applications and Impact of Nanomaterial’ by Mark. R. Weisner and Jean-Yves Bottero, 2nd edition, The McGraw-Hill Companies, 2016.

	Semester: I	
Course Name: Introduction to Nanoelectronics and Quantum Devices		**Course Code: NTTE-510**
Course type: DSC		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:
The Introduction to Nanoelectronics and Quantum Devices course is designed to provide students with a comprehensive understanding of the fascinating and cutting-edge field of nanoelectronics and quantum devices. In this course, students will explore the fundamental principles, theories, and applications of nanoscale electronic devices and quantum phenomena that underpin the next generation of advanced technologies.

Prerequisites:

A good understanding of classical mechanics, electromagnetism, and quantum mechanics is essential. Topics such as wave-particle duality, energy levels, and quantum states are relevant to nanoelectronics and quantum devices.
Familiarity with basic electronic principles, such as voltage, current, resistance, capacitance, and inductance, is necessary. Understanding concepts like semiconductor devices (e.g., diodes, transistors) and their behavior will be helpful.

Learning Outcomes (LO):

- Understand the fundamental principles of nanoelectronics and quantum devices.
- Describe the behavior of electrons at the nanoscale and their interactions with quantum systems.
- Explain the principles of quantum mechanics relevant to nanoelectronic devices.
- Analyze the application of quantum principles in electronic components.
- Gain insights into the behavior of quantum dots, quantum wells, and other quantum devices.
- Understand quantum tunneling and its significance in nanoelectronics.
- Explore the potential of nanoelectronics in future technologies and quantum computing.
- Discuss the challenges and opportunities in nanoelectronics research.
- Gain hands-on experience in the fabrication and characterization of nanoelectronic devices.
- Analyze the impact of nanoelectronics on various industries and societal applications.

Course Outline:

Unit 1: Nanoscale Electronics Fundamentals: Introduction to nanoelectronics and its importance in modern technology. Basic semiconductor physics and band theory. Quantum mechanics and its relevance to nanoscale electronic behavior. The role of quantum confinement in nanoelectronic materials. Behavior of electrons in low-dimensional structures (quantum wells, quantum dots). Energy states and density of states in nanoscale materials. Fabrication techniques for nanoscale electronic components. Overview of nanoscale transistors and electronic devices.

Unit 2: Quantum Devices and Applications: Introduction to quantum devices and their significance. Quantum tunneling and its implications in nanoelectronics. Quantum dots and their applications in quantum computing. Quantum wells and their use in lasers and photodetectors. Single-electron devices and their unique behavior. Spintronics and its potential in future electronics. Nanoscale optoelectronic devices and photodetectors. Quantum cryptography and secure communication.

Unit 3: Emerging Trends in Nanoelectronics: Introduction to quantum computing and its principles. Topological insulators and their role in quantum devices. Nanoelectronics in biomedical applications and sensors. Nanoelectronics for energy harvesting and storage. Nanoelectronics in flexible and wearable electronics. Challenges in nanoelectronics research and potential solutions. Ethical considerations and societal impact of nanoelectronics. Future prospects and innovations in nanoelectronics.

Text Books and References:

1) Nanoelectronics: Devices, Circuits and Systems (Micro and Nano Technologies) by Brajesh Kumar Kaushik, Elsevier
2) Introduction to Nanoelectronics: Science, Nanotechnology, Engineering, and Applications by Michael A. Stroscio, Cambridge University Press
3) Nanoelectronics: Physics, Materials and Devices by Arezki Benfdila, Elsevier
4) Nanoelectronics Fundamentals Materials, Devices and Systems by Hassan Raza, Springer

	Semester: I	
Course Name: Research Methodology-I		**Course Code: NTRM-511**
Course type: DSC		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

The Research Methodology in Nanotechnology course is designed to provide students with a comprehensive understanding of the fundamental principles, tools, and techniques used in conducting research in the field of nanotechnology. Through this course, students will develop critical thinking skills, learn how to design and execute effective experiments, and gain hands-on experience in analyzing and interpreting nanoscale phenomena.

Prerequisites:

1. Define the concept of research and outline the key steps in the research process, including research methods and approaches.
2. Develop a solid understanding of qualitative research methods and techniques, including their application and validation.
3. Master the essential components of the research process to effectively strategize and execute research projects.
4. Explore the intricacies of research publication processes, delving into the journey from data collection to sharing findings with the academic community.
5. Cultivate the skills required to proficiently present, assess, and publish scientific articles, ensuring effective communication of research outcomes.
6. Define the concept of research and outline the key steps in the research process, including research methods and approaches.
7. Develop a solid understanding of qualitative research methods and techniques, including their application and validation.
8. Master the essential components of the research process to effectively strategize and execute research projects.
9. Explore the intricacies of research publication processes, delving into the journey from data collection to sharing findings with the academic community.
10. Cultivate the skills required to proficiently present, assess, and publish scientific articles, ensuring effective communication of research outcomes.

Learning Outcomes (LO):

- Understand the principles and fundamentals of nanotechnology research, including its applications and significance in various fields.

- Demonstrate knowledge of various nanomaterials, nanodevices, and nanoscale phenomena, and their relevance to nanotechnology research.

- Identify and evaluate appropriate research topics and research questions within the field of nanotechnology.

- Develop a comprehensive understanding of different research methodologies and techniques commonly employed in nanotechnology research.

- Formulate research hypotheses and design experiments to test them, considering the unique challenges and opportunities presented by nanoscale investigations.

- Define the concept of research and outline the key steps in the research process, including research methods and approaches.

- Develop a solid understanding of qualitative research methods and techniques, including their application and validation.
- Master the essential components of the research process to effectively strategize and execute research projects.
- Explore the intricacies of research publication processes, delving into the journey from data collection to sharing findings with the academic community.
- Cultivate the skills required to proficiently present, assess, and publish scientific articles, ensuring effective communication of research outcomes.

Course Outline:

Unit I: Research Basics and Problem Identification (10 Hours)

Research Basics: Definition of Research, Objectives of Research, Characteristics of Research, Motivation for Research, Importance of Research, Qualitative and Quantitative Research: Qualitative Research, Quantitative Research, Concept of Measurement, Causality, Generalization, Replication, Merging the qualitative and quantitative approaches
Research Design: Understanding the concept and significance of research design. Characteristics of an effective research design. Exploratory Research Design: Definition, various types, and applications. Descriptive Research Designs: Explanation of the concept, diverse types, and practical uses. Experimental Design: Grasping the concepts of independent and dependent variables. The utility of case studies in research.

Unit II: Defining the Research Problem (10 Hrs.)

The process of defining problems: Sequential stages in identifying issues. Crafting problems: Shaping and framing research challenges, the essence of hypotheses: Grasping the concept of hypotheses, their role in testing. Hypothesis testing: Methods and procedures for evaluating hypotheses. Executing the research plan, Understanding the results and communicating them effectively, How hypotheses influence decision-making, Case Studies, Data Interpretation, Understanding measurement: Defining what is measured. Measurement challenges in research: Issues of validity and reliability. Levels of measurement: Nominal, ordinal, interval, and ratio scales.

Unit III: Drafting Research Proposals and Reports (10 Hours)

Introduction to research proposal writing and costing. Components of a research proposal: rationale, objectives, methodology, target audience, research centers, sample details, and sampling methods. The execution of research projects, including research units. An overview of research report and proposal writing. Types of research reports and practical guidelines for creating them. Step-by-step approach to writing reports. How to present a report effectively. Typing, documentation, bibliography, and formatting tips for quality research reports. Layout considerations for research papers. Understanding Journals and their impact factors. Deciding when and where to publish research findings. Ethical considerations in publishing, including plagiarism and self-plagiarism. Case studies for practical insight.

Text Books and References:

1. Research Methodology. Methods and Techniques: C. R. Kothari.
2. Research Methodology: Tools and Techniques by Dr. Prabhat Pandey, Dr.Meenu Mishra Pandey

	Semester: I	
Course Name: Research Methodology-II		Course Code: NTRM-512
Course type: DSC		
Total contact hours: 60	Theory Credit: 2	Marks: 50

Course Description:

The Research Methodology in Nanotechnology course is designed to provide students with a comprehensive understanding of the fundamental principles, tools, and techniques used in conducting research in the field of nanotechnology. Through this course, students will develop critical thinking skills, learn how to design and execute effective experiments, and gain hands-on experience in analyzing and interpreting nanoscale phenomena.

Prerequisites:

Students should have a fundamental understanding of nanotechnology principles, concepts, and applications. This includes knowledge of nanomaterials, nanofabrication techniques, nanodevices, and nanoscale phenomena.

Nanotechnology is an interdisciplinary field that often combines principles from various branches of science and engineering. Students should have a background in a related field such as physics, chemistry, materials science, electrical engineering, or mechanical engineering..

Learning Outcomes (LO):

- Analyze and interpret experimental data obtained from nanotechnology research, using appropriate statistical methods and data analysis tools.
- Critically evaluate existing literature and research publications in nanotechnology, recognizing the significance and limitations of prior work.
- Understand ethical considerations and safety protocols specific to nanotechnology research and demonstrate responsible conduct in laboratory settings.
- Communicate research findings effectively through oral presentations, written reports, and scientific publications in accordance with established standards in the field.
- Work collaboratively in interdisciplinary research teams, appreciating the diverse perspectives and expertise required for successful nanotechnology research.
- Apply problem-solving and critical thinking skills to address challenges encountered during nanotechnology research projects.
- Demonstrate proficiency in using advanced instrumentation and tools commonly used in nanotechnology research.
- Evaluate the potential societal and environmental impacts of nanotechnology research and propose responsible approaches for its application and development.
- Gain awareness of funding opportunities and research grants available for nanotechnology projects and develop proposal writing skills.

Course Outline:

In this segment of the course, we will emphasize practical aspects, including presentations, case studies, assignments, and tutorials.
Students are expected to complete the following tasks:

1. Choose a Broad Research Project Topic (to be initiated in the second semester).
2. Gain familiarity with the Fundamental Concepts and Principles of your chosen Research Topic.
3. Identify 10 Journals Indexed in SCOPUS or WEB OF SCIENCE that are relevant to your Broad Topic.
4. Search for and Download 20 Research Articles from the aforementioned Journals.
5. Conduct a Systematic Review of these 20 Research Articles.
6. While Analysing Each of the 20 Research Articles, Create Notes Covering the Following Aspects:
   a) Research Article Objectives
   b) Employed Methodology
   c) Key Findings
   d) Relevance of Results to Current Field Advancements
   e) Uniqueness of the Research Article
   f) Notable Limitations Present in the Research Article
   g) Proposed Solutions for Addressing these Limitations
7. Formulate a well defined Title for your Research Project.
8. Develop a Hypothesis for your Research.
9. Outline Your Research Objectives and Methodological Approach.
10. Draft Expected Outcomes of your Research Project.

Upon completion of these tasks, students should compile a report that includes the following elements:

i) Well defined Title of the Research Project
ii) Fundamental Aspects of the Research Topic
iii) Hypothesis
iv) Objectives
v) Methodology
vi) Elaborate Experimental Plan
vii) Expected Outcomes
viii) List of References

By engaging in this comprehensive assignment, students will establish a robust foundation for their research projects and cultivate essential skills in literature review, hypothesis formulation, and project planning.

Text Books and References:

1. Research Methodology. Methods and Techniques: C. R. Kothari.
2. Research Methodology: Tools and Techniques by Dr. Prabhat Pandey, Dr.Meenu Mishra Pandey
3. Research Methodology by Dr. S. L. Gupta, Hitesh Gupta; International Book House Pvt Ltd (2013), ISBN-10: 8191064278, ISBN- 13: 978-8 191064278
4. Basic Research Methods-Gerard Guthrie SAGE Publications, India, Pvt Ltd, New Delhi (2010), ISBN-10: 8132104579, ISBN- 13: 978-8 132104575
5. Research Methodology-methods and techniques By C. R. Kothari, New Age International Publishers (2011) ISBN 978-8 1-224-1522-3
6. Principles of Research Methodology- Phylli s G. Supino, Jeffrey S. Borer; Springer, Verlag New York (2012), JSBN-ebook: 1461433592, ISBN (Hardcover): 978- 146 1433590
7. Research Design Qualitative, Quantitative. and Mixed Methods Approaches- John W.Creswell; SAGE Publications Ltd, UK (201 1), ISBN-9780857023452
8. Research Methodology -A Step-by-Step Guide for Beginners- Ranj it Kumar; Sage Publications

Ltd (2010), ISBN- 18492030 16.
9. Scientific Writing and Communication- Angelika Hofmann; Oxford University Press, US (2010), ISBN- 13-: 978-0 199947560, ISBN-10: 01 99947562
10. Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded Joshua Schimel, Oxford University Pre ss, (2011), ISBN: 9780199760237
11. Handbook of Scientific Proposal Writing- A. Yavuz Oruc; CRC Press, Taylor & Francis group (2011), ISBN: 9781439869185

	Semester: II	
Course Name: Nanomaterials Based Devices: MEMS and NEMS		Course Code: NTTC-550
Course type: DSC		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

To provide the students with the understanding of micro-electro mechanical and nano-electro mechanical systems, so that they become familiar with the fabrication and design principles of various devices.

Prerequisites:

Familiarity with materials science concepts such as crystal structures, material properties (e.g., mechanical, electrical, and thermal), and the relationship between microstructure and properties will be valuable.
Familiarity with mechanical engineering concepts will be beneficial, as MEMS and NEMS devices involve mechanical components.

Learning Outcomes (LO):

- Students will get to know the working principle of transistor.
- Students will get to know the metal semiconductors contacts and their basic characteristics.
- Students will get to know the working principle of sensors and micro-actuation, MEMS and NEMS.
- Students will get to know the micro-system packaging, simulation and design tools.
- Students will get to know the challenges of nano-electronic manufacturing technology.

Course Outline:

Unit 1: Semiconductor: formation energy and band diagram, intrinsic carrier concentration, donors and acceptors, nondegenerate and degenerate semiconductors, mobility, carrier diffusion, current density, recombination processes, continuity equation. P-N junction diode, thermal equilibrium condition, depletion region, depletion capacitance current voltage characteristics and temperature effect, charge storage and transistor behavior, junction breakdown. Sensors- working principle of sensors, types of sensors, static characteristics and dynamic characteristics-mechanical, optical, spintronic, bio-electronic and bio-magnetic sensors-surface modification-surface materials and interactions, micro-actuation, scaling laws. Metal semiconductor contacts, basic characteristics, Schottky barrier, Ohmic contact, MOS structure, MIS diode, operation and its characteristics,

Unit 2: MEMS and NEMS: definitions, synthesis and design. Materials for MEMS & NEMS- active substrate materials and polymers. Consideration for microfabrication materials, LIGA process, microsystem packaging, die, device and system level packaging, interfaces in microsystem packaging for different application, signal mapping and transduction, micro system design consideration, process design, mechanical design, mechanical design using Fem, design considerations for optical, fluidic, RF and bio MEMS & NEMS,.

Unit 2: Biomimetic devices- biological analogies and design–biomimetic fundamentals, biomimetic for NEMS and MEMS. Nano machines and molecular electronics. Nano-ICs and nano-computer architectures - quantum computation and introduction to nanoelectronics, future of nanoelectronics - interfacing with the Brain, labon-biochips, challenges and solutions in nano manufacturing technology.

Text Books and References:

1. ‘Micro-Electro Mechanical and Nano-Electro Mechanical Systems, Fundamental of Nano-and Micro-Engineering’ by Sergey Edward Lyshevski, Lyshevski Edward Lyshevski, CRC Press, 2nd Ed. 2005.
2. ‘Nanomaterials: Synthesis, Properties and Applications Institute of Physics’ by Edelstein. A. S, and Cammarata, Bristol, Philadelphia: Institute of Physics 2002.
3. ‘Micro manufacturing and Nanotechnology’ by Mahalik. N. P, Springer Berlin Heidelberg New York 2006.
4. ‘Micro and Nanomanufacturing’ by Mark. J Jackson, Springer. 2nd edition 2008.
5. ‘Nanofabrication, Principles, Capabilities and Limits’ by Zheng Cui Springer, 2008.
6. ‘Nanotechnology Enabled Sensors’ by Kalantar–Zadeh. K., Springer 2010.
7. ‘Future Trends in MicroElectronics’ by Serge Luryi, Jimmy Xu, Alex Zaslavsky, John Wiley & Sons, Inc. Hoboken, New Jersey 2007.

	Semester: II	
Course Name: Physics of Nanomaterials		**Course Code: NTTC-551**
Course type: DSC		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

To provide the students with the physics of nanomaterials and the origin of various physical properties, so that they become familiar with the underlying basic principles.

Prerequisites:

A solid understanding of classical mechanics, electromagnetism, thermodynamics, and quantum mechanics is essential. This typically includes topics such as Newton's laws, Maxwell's equations, the laws of thermodynamics, and the Schrödinger equation.
Familiarity with solid-state physics is beneficial, as nanomaterials are often considered within the context of condensed matter physics. Topics like crystal structures, band theory, and electronic properties of solids are relevant.

Learning Outcomes (LO):

- Students will get to know the lattice dynamics and thermal properties.
- Students will get to know the band theory and the origin of various physical properties.
- Students will get to know the electrical and thermal transport properties and estimation of relaxation time.
- Students will get to know the fabrication of field effect transistors made of nanowires and graphene.

Course Outline:

Unit 1: **Overview Lattice structures:** bindings in solids, elastic constants, lattice vibrations, normal modes, density of states, conductivity and band gap, metal to insulator transition. Overview of reciprocal lattice, Brillouin zone, quantization of elastic waves, phonon momentum, density of states.
Overview of band theory of solids, bands in pure and doped semiconductors, Drude and Sommerfield models and their failures, review of electrons in a periodic potential, Bloch theorem, nearly free electron model, tight binding method, Van hove singularities, dispersion relations of graphene and carbon nanotubes using tight binding method.

Unit 2: Band structure engineering: - semiconductor alloys, semiconductor multilayers/hetero-structures, envelope function approximation in hetero-structures, heterojunction and modulation doping, super lattice formation -Kronig - Penney model of super lattice.
Electronic transport theory- from classical kinetic theory, calculation of relaxation time in metals and insulators, electronic transport in 1, 2 and 3 dimensions, energy sub-bands, effective mass, Drude conduction, ballistic transport, phase coherence length, quantized conductance. Landau equation, ballistic transport in carbon nanotubes, Luttinger liquid model for 1D conductors.

Unit 3: Quantum dots: - electron confinement, single and interacting quantum dots. Lithographic fabrication of III-V and graphene quantum dots. PL, Raman and optical spectroscopy to characterize quantum dots, Kondo Effect in quantum dots. Coulomb blockade in a nanocapacitor, Fock space, tunnel junctions and excitations by a current source, coulomb blockade in a quantum dot circuit, single electron transistor, examples of nanoscale field effect transistors made of nanowires and graphene.

Text Books and References:

1. 'Optics and Spectroscopy at Surfaces and Interfaces' by Vladimir. G, Bordo and Horst-Günter Rubahn; John-Wiley and Sons, Inc. 2005.

2. ‘Modern Optical Spectroscopy’ by William. W, Parson, Springer 2007.
3. ‘Fundamentals of Molecular Spectroscopy’ by Collin Banwell, Mc Cash, McGraw Hill, 4th edition 2017.
4. ‘Introduction to Atomic Spectra’ by Harvey Elliot White, McGraw Hill 1934.
5. ‘Chemical Analysis-Modern Instrumentation Methods and Techniques’ Francis Rouessac and Annick Rouessac, Wiley, 2nd edition 2013.
6. ‘Principles of Fluorescence Spectroscopy’ by Joseph. R, Lakowicz, Springer, 3rd edition 2010.
7. ‘Introduction to Spectroscopy’ by Pavia, Lampman, Kriz, Vyvyan, Cengage Learning, 5 th Edition 2014.
8. ‘Optical Properties and Spectroscopies of Nanomaterials’ by Jin Jhong Jhang, World Scientific Publishing 2009.
9. ‘Introduction to Solid State Physics’ by C. Kittel, Wiley Eighth edition 2012.
10. ‘Introduction to Nanotechnology’ by Owen and Poole, Wiley. First edition, 2008
11. ‘Quantum Wells, Wires & Dots: Theoretical & Computational Physics of Semiconductors Nanostructures’ by Paul Harrison, Wiley–Blackwell, 2nd edition 2005.
12. ‘Nanoelectronics and Nanosystems’ by Karl Goser, Peter Glösekötter, Jan Dienstuhl Springer 2004.

	Semester: II	
Course Name: Characterization Techniques For Nanomaterials		**Course Code: NTTC-552**
Course type: DSC		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

This course is intended for the students to teach important techniques, basic principles and sample preparation for the analysis, so that they become familiar with characterization of various nanomaterials.

Prerequisites:

Familiarity with materials science principles is essential. You should have a basic understanding of material properties, crystal structures, phase transitions, and material processing techniques.
Basic knowledge of common laboratory instrumentation and analytical techniques such as microscopy (electron microscopy, atomic force microscopy), spectroscopy (UV-Vis, FTIR, Raman), and X-ray diffraction can be beneficial.

Learning Outcomes (LO):

- Students will get to know the working principle of various characterization techniques specific to nanomaterials.
- Students will get to know the instrumentation aspects.
- Students will become familiar with data interpretation.
- Students will learn the sample preparation methods and sample handling.
- Students will acquire the ability to analyse the data obtained from various characterization techniques.
- Students will be able to identify the ideal method of analysis to draw the required information.

Course Outline:

Unit 1: Spectroscopic Techniques: Theory and origin of optical properties - UV visible and photoluminescence. Simplified model for vibrational interactions - characteristic bands, attenuated-total reflection (ATR) and grazing incidence angle techniques - reflection absorption IR spectroscopy (RAIRS)- FTIR and Raman spectroscopy. The Raman effect - lateral and in-depth resolution of conventional μRS, resonant Raman spectroscopy (RRS). Surface-enhanced Raman spectroscopy (SERS)- nano Raman - phase identification and phase transitions in nanoparticles. Raman and optical spectroscopy to characterize quantum dots & CNTs - absorption saturation and harmonic generation, second-harmonic generation (SHG) and sum frequency spectroscopy (SFG). Ultraviolet photo electron spectroscopy (UPS) and X-ray photoelectron spectroscopy. X-ray photoluminescence, chemiluminescence, and X-ray fluorescence spectroscopy (XRF) - X-ray beam effects, spectral analysis - core level splitting of linewidths - elemental analysis, qualitative and quantitative secondary structures, XPS-imaging. Atomic emission spectroscopy.
Auger electron spectroscopy (AES) - basic principles, instrumentation and experimental procedures, sample preparation, and applications of electron energy loss spectroscopy for nanomaterials. Reflection high energy electron diffraction (RHEED) for surface analysis.

Unit 2: Structural techniques: Powder X-ray diffraction and small angle X-ray scattering- Bragg's law and determination of crystal structure - applications in determination of particle size. Spontaneous emission - classical bound and quantum mechanical radiative decay, absorption and emission - absorption coefficient and absorption cross-section. Absorption and induced emission- nano optics and localized surface plasmon spectroscopy, scanning plasmon near-field optical spectroscopy (SPNM) - introduction to near-field optical spectroscopy & nonlinear optics. Basic understanding of each technique with special emphasis on characterization at nanoscale.

Unit 3: Microscopic and other advanced techniques: Scanning electron microscopy (SEM) and transmission electron microscopy (TEM)- working principal, instrumentation and applications - sample preparation methods, advantages and limitations- image interpretation, bright field and dark field imaging- issues with electron optics.

Optical properties - interaction between nanoparticles. Direct and indirect gap transitions. Dynamic light scattering spectroscopy (DLS) - size determination using DLS.

Scanning probe techniques- basic principle of scanning tunnelling spectroscopy, instrumentation and applications, constant current and constant height mode. Atomic force microscopy - tip-surface interaction, different imaging modes, force sensor, deflection detection, working with biological samples. Basic understanding of each technique with special emphasis on characterization at nanoscale.

Text Books and References:

1. ‘Optics and Spectroscopy at Surfaces and Interfaces’ by Vladimir. G, Bordo and Horst-Günter Rubahn; John-Wiley and Sons, Inc. 2005.
2. ‘Modern Optical Spectroscopy’ by William. W, Parson, Springer 2007.
3. ‘Fundamentals of Molecular Spectroscopy’ by Collin Banwell, Mc Cash, McGraw Hill 4th edition 2017.
4. ‘Introduction to Atomic Spectra’ by Harvey Elliot White, McGraw Hill 1934.
5. ‘Chemical Analysis-Modern Instrumentation Methods and Techniques’ by Francis Rouessac and Annick Rouessac, Wiley 2nd edition 2013.
6. ‘Principles of Fluorescence Spectroscopy’ by Joseph. R, Lakowicz, Springer. 5th edition 2010.
7. ‘Introduction to Spectroscopy’ by Pavia, Lampman, Kriz, Vyvyan, Cengage Learning. 5th edition 2014.
8. ‘Optical Properties and Spectroscopies of Nanomaterials’ by Jin Jhong Jhang World Scientific Publishing 2009.

	Semester: II	
Course Name: Carbon Nanomaterials: Synthesis, Functionalization and Applications		**Course Code: NTTC-553**
Course type: DSC		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

This course is intended for the students to provide the structural and electronic properties of carbon nanomaterials as well as the device structures and operation. This course is also intended for the students to become familiar with functionalization carbon nanomaterials for various applications

Prerequisites:

A fundamental understanding of chemistry, including concepts such as atomic structure, chemical bonding, and reaction mechanisms, is essential to comprehend the synthesis and functionalization processes of carbon nanomaterials.
If the course involves hands-on laboratory work, students may need to complete safety training or have prior experience with laboratory protocols.

Learning Outcomes (LO):

- Students will get to know the methods of synthesis and variation of properties of carbon nanomaterials.
- Students will get to know the use of carbon nanomaterials as active components in electronic devices.
- Students will get to know the various applications of carbon nanomaterials.

Course Outline:

Unit 1: Introduction-carbon materials: – carbon molecules- nature of the carbon bond, allotropes of carbon – new carbon structures, discovery of C60 - structure of C60 and its crystal. Structure of carbon nanotubes (CNTs) – types of CNTs–electronic properties of CNTs – band structure of CNTs and graphene – electron transport properties of CNTs – scattering in CNTs – carrier mobility in CNTs. From a graphene sheet to a nanotube, structure of graphene and single wall and multi walled nanotubes, zigzag and armchair nanotubes, nomenclature, Euler's theorem.
Structure of higher fullerenes, growth mechanisms- CNTs.

Unit 2: Production techniques and purification: CVD synthesis – method – direct incorporation with device fabrication process– SWNT synthesis on metal electrodes – lowering the synthesis temperature – controlling the SWNT growth – location, orientation, chirality – narrowing diameter distributions – chirality distribution analysis for different CVD processes – selective removal of the metallic nanotubes and integration with FET devices. Graphene and fullerene preparation - synthesis of graphene by various physical and chemical methods and purification, pyrolysis of hydrocarbons, partial combustion of hydrocarbons, arc discharge methods, production by resistive heating, rational syntheses.

Unit 3: Surface modifications and devices of carbon nanomaterials: physical, chemical, and electrochemical methods. Physical properties - electronic properties, band structure of graphene – mobility and density of carriers, spectroscopic properties of carbon nanostructures - Raman, FTIR, absorption and emission spectroscopy, ESR - spectroscopic studies.
Application of fullerene, CNT, graphene and other carbon nanomaterials - mechanical, thermal, electronic, and biological devices. Schottky barrier in CNT-FET, performance of CNT interconnects, circuit models for CNTs/graphene, quantum capacitance, chemical doping, hysteresis and device passivation, metal contacted MOSFETs, CNT Composites of carbon nanomaterials and their

applications in paint industry, aerospace industry, electronics, etc.

Text Books and References:

1. ‘Carbon Nanotube Electronics’ by Ali Javey and Jing Kong, Springer Science media 2009.
2. ‘Carbon nanotubes: Properties and Applications’ by Michael. J, O’Connell, CRC/Taylor & Francis 2006.
3. ‘The Physics of Carbon Nanotube Devices’ by Francois Leonard, William Andrew Inc. 2009.
4. ‘Physical properties of Carbon Nanotubes’ by G Dresselhaus, Mildred S Dresselhaus, Riichiro Saito, Imperial College Press 1998.
5. ‘Carbon Nanotubes: Properties and Applications’ by Michael J. O'Connell, CRC Press. 2018.
6. ‘Nanotubes and Nanowires’ by C. N. R. Rao and A. Govindaraju, Royal Society of Chemistry. 3rd edition 2021.
7. ‘Carbon Nanotubes: Preparation and Properties’ by Joseph C. Salamone (Ed.) CRC Press. 1996.
8. ‘Carbon Nanotubes and Graphene’ by Kazuyoshi Tanaka (Ed.), S. Iijima (Ed.) Elsevier 2nd edition 2014.

	Semester: II	
Course Name: Laboratory Course IV, V and IV		**Course Code: NTLC-554,55,56**
Course type: DSC		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

To provide the students with basic knowledge of simulation and theoretical studies in nanoscience and nanotechnology.

Prerequisites:

A strong foundation in general chemistry is crucial since nanoscience and nanotechnology involve understanding chemical reactions and materials at the atomic and molecular level.
Familiarity with the basic principles of materials science and engineering will be beneficial, as nanotechnology often involves manipulating and characterizing materials at the nanoscale.

Learning Outcomes (LO):

- Students will get to know basic universal safety standards and practices in laboratories.
- Students will get to some of the chemical synthesis of nanomaterials.
- Students will get to know some of the characterization methods for nanomaterials.
- Students will get to know 2D surfaces, oxide nanomaterials, and metal nanoparticles.

Course Outline:

NTLC-554:
1. Fabrication and Testing of Nanoscale Gas-Sensors
2. Investigation of Nanocomposites for Supercapacitor application
3. Preparation and Characterization of Nanoparticles for Photocatalytic Dye degradation application
4. Fabrication of MEMS Devices using Nanolithography Techniques
5. Investigation of Nanocomposites for Battery application

NTLC-555:
1. Hall effect measurement.
2. Four probe conductivity measurement.
3. Dielectric constant as a function of temperature.
4. Electronic Structure investigation of Nanomaterials using Density functional Theory (DFT)
5. Analysis of Nanomaterials for Solar cell applications
6. Preparation and Testing of Nanomaterials for Flexible Electronics
7. Theoretical Characterization of solar cells using SCAPS 1D

NTLC-556:
1. Analysis of Surface Morphology of Nanomaterials using Scanning Electron Microscopy (SEM)
2. Characterization of Nanoparticle Shape and Size using Transmission Electron Microscopy (TEM)
3. Determination of Surface Area of Nanomaterials through BET Analysis
4. Analysis of Nanoparticle Composition by Energy Dispersive X-ray Spectroscopy (EDS)
5. Investigation of Nanomaterials' Chemical Structure using Fourier Transform Infrared (FTIR) Spectroscopy
6. Characterization of Nanoscale Mechanical Properties using Atomic Force Microscopy (AFM)

	Semester: II	
Course Name: Advancement in Bionanotechnology		Course Code: NTTE-557
Course type: DSE		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

To provide the students with the knowledge of recent advancement in nanobiotechnology, so that they would be able to apply their knowledge in industrial applications.

Prerequisites:

Strong fundamentals in biology, chemistry, physics, and mathematics are essential. You should have a good understanding of cell biology, molecular biology, biochemistry, and organic chemistry.
An understanding of the ethical considerations and safety measures in working with nanomaterials and biological systems is critical. Bionanotechnology can have significant implications, so ethical awareness is essential.
Bionanotechnology is an interdisciplinary field, so the ability to integrate knowledge from various domains is vital for success.

Learning Outcomes (LO):

- Students will get to know the advanced nanobiotechnology.
- Students will get to know various assays and working antimicrobial drugs.
- Students will get to know the fundamentals of biomechanics and biotribology.
- Students will get to know various nanotechnology devices for the detection and diagnostics.
- Students will get to know the applications and possibilities of biomaterials like tissue engineering to enhance the quality of life.
- Students will get to know the targeted drug delivery mechanism.
- Students will get to know the advancement in nanotechnology based cancer therapy.

Course Outline:

Unit 1: Bioevaluation of Nanomaterials: Study of antimicrobial activity of nanoparticles. Bacterial growth inhibition assay, minimum inhibitory concentration (MIC). Introduction to bio-electromagnetism, neuro-transport, nerve impulse conduction and conduction across synapse, working of EEG & ECG. Concepts of biomechanics, bio-tribology, biological/circadian rhythms and phase markers.
Protein-based Nanostructures. Nanopump and molecular motors- types and examples. Self-assembly - from natural to artificial structures. Nanotechnology based microfluidics - nano printing of DNA, RNA, and proteins, devices to detect a single molecule of DNA.

Unit 1: Nanodiagnostics: - rationale of nanotechnology for molecular diagnostics, nanoarrays for molecular diagnostics, nanorobotics. Nanoparticles for molecular diagnostics – gold nanoparticles and Q-dots for molecular diagnostics - magnetic nanoparticles –use in immunohistochemistry - imaging applications of nanoparticles. AFM in study of bio-molecules.
DNA nanomachines for molecular diagnostics, nanobarcodes technology and SNP genotyping, nanobarcode for multiplexed gene expression profiling. Cantilevers as biosensors for molecular diagnostics, carbon nanotube biosensors, FRET based DNA nanosensors. Ion channel switch biosensor technology, electronic nanobiosensors, electrochemical nanobiosensors, quartz nanobalance and viral nanosensors, optical biosensors, erasable biodetectors.

Unit 2: Nanomaterials for drug discovery and therapy: - cells targeting by nanoparticles, nanovectors, nanotechnology enabled drug design. Dendrimers -dendritic nanostructures, chemical

structures, interaction between drug molecules and dendrimers, applications of dendrimers as drugs. Nanomaterials for targeted drug delivery, viruses as nanomaterials for drug delivery. Trojan nanoparticles, self-assembling nanoparticles for intracellular drug delivery - nanoparticle combinations with liposomes hybrids - nanomolecular valves for controlled drug release - nanomotors. Nanotechnology for point-of-care diagnostics. Applications of nanotechnology in food microbiology.
Nanotechnology in cancer therapy – passive targeting of tumors - pathophysiological principles and physicochemical aspects of delivery systems - active targeting strategies. Pharmacokinetics of nanocarrier – mediated drug and gene delivery - multifunctional nanoparticles for cancer therapy. Neutron capture therapy of cancer – nanoparticles and high molecular weight boron delivery agents. Nanotechnology for - oncology, neurology, cardiology, orthopaedics, and ophthalmology.

Text Books and References:

1. 'Introduction to Novel Drug Delivery Systems' by N. K. Jain, Vallabh Prakashan 2017.
2. 'Understanding Nanomedicine: An Introductory Textbook' by Rob Burgess, Jenny Stanford Publishing 2012.
3. 'Nanomedicine for Drug Delivery and Therapeutics' by Ajay Kumar Mishra, Wiley, 2013.
4. 'Medical Nanotechnology and Nanomedicine' by Harry F. Tibbals, CRC Press 2017.
5. 'Introduction to Nanomedicine and Nanobioengineering' by Paras N. Prasad. Wiley 2012.
6. 'The Handbook of Nanomedicine' by Kewal. K. Jain, Humana 2014.
7. 'Nanomedicine: A Systems Engineering Approach' by Zhang Jenny Stanford Publishing 2009.
8. 'Nanomedicine Volume IIA: Biocompatibility' by Robert. A, Freitas Jr., CRC Press 2003.

	Semester: II	
Course Name: Scientific Computation and Simulation in Nanoscience & Nanotechnology		**Course Code: NTTE-558**
Course type: DSE		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:
To provide students with the basic knowledge and hands on experience of programming and simulation and to introduce the students to the solution techniques for the physical models.

Prerequisites:

Understanding basic chemistry concepts will be helpful, as nanoscience frequently involves chemical interactions and reactions at the nanoscale.
Proficiency in programming languages is a must. Most scientific simulations in nanoscience are done using programming languages like Python, C++, or Fortran. You should be comfortable with writing and debugging code.
Familiarity with numerical methods and computational techniques is essential. This includes understanding finite difference, finite element methods, molecular dynamics, and Monte Carlo simulations, among others.

Learning Outcomes (LO):

- Students will get hands on experience to develop scientific models, analytical and computation skills.
- Students will be able to build the mathematical models of the physical systems of interest and simulate the effect of changes in a system.
- Students will get to know the simulation and analysis techniques.

Course Outline:

Computational programming: Student will be required to develop and execute six or more programs using C^{++} language platform on the following projects:
i. Gauss elimination method
ii. Guass Jordon
iii. Jacobi iterative method
iv. Gauss seidel iterative method
v. Lagrange interpolation polynomial
vi. SPLINE vii. Linear regression
viii. Find derivative using forward difference formula
ix. Trapezoidal method
x. Simpson's 3/8 method
xi. Euler's method xii. Runge Kutta Method

Analytical Techniques: Student will get hands on experience on Origin Lab software and perform data analysis and modelling using the inbuilt examples. Band structure and physical property modelling: Student will get hands on experience on understanding the Density Functional Theory (DFT) based materials properties simulations using either VASP or Quantum Expresso software tools. Using this software, a minimum of two of the materials property projects will be executed to understand the band structure and optical properties of metals/semiconductors/insulators and their nanostructures. Solution for systems of non-linear equations. Introduction to finite difference time domain and green functions for nanoscale materials systems.

Text Books and References:

1. ‘Numerical Methods for Scientific and Engineering Computation’ by M. K. Jain, S. R. K. Iyengar and R. K. Jain, New Age International Pvt Ltd Publishers. 1996.
2. ‘Handbook of Theoretical and Computational Nanotechnology’ Eds. Michael Rieth and Wolfram Schommers, American Scientific Publishers, 2006.
3. ‘Introductory Computational Physics’ by Andi Klein and Alexander Godunov, Cambridge University Press, August 2010.
4. ‘Modelling Molecular Structures’ by Allan Hinchliffe, 2nd edition, Wiley–Blackwell 1995.
5. ‘Higher Engineering Mathematics’ by B. S. Grewal, KHANNA PUBLISHERS 44th Edition 1965.
6. ‘Introductory Numerical Analysis’ By S. S. Sastry, Prentice Hall India Learning Private Limited. 4th edition 2005.
7. ‘Computer Arithmetics for Nanoelectronics’ by Vlad P. Shmerko, Svetlana N. Yanushkevich, Sergey Edward Lyshevski CRC Press 2017.
8. ‘Introduction to Logic Design’ by Svetlana N. Yanushkevich, Vlad P. Shmerko Taylor and Francis Group 2008.
9. ‘C++ Programming Language’ by Bjarne Stroustrup Addison-Wesley 2013.
10. ‘Algorithms and Data Structures in C++’ by Leen Ammeraal John Willey & Sons 1996.
11. ‘DFT Study of Properties of Surface Passivated Silicon Nanoclusters’ by Chopra Siddheshwar and Rai Bandana Lambert Academic Publishing 2015.

	Semester: II	
Course Name: Nanocomposites-Fabrication, Properties, and Applications		**Course Code: NTTE-559**
Course type: DSE		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:
To provide the students with the knowledge of synthesis, properties, and applications of composite and nanocomposite materials, so that they would be able to understand their industrial use.

Prerequisites:

Understanding the fundamentals of chemistry and materials science is crucial for comprehending nanocomposites' behavior, properties, and fabrication processes.
Familiarity with various analytical techniques used to characterize materials at the nanoscale, such as electron microscopy, X-ray diffraction, and spectroscopy, can be helpful.
Knowledge of engineering principles will aid in understanding how nanocomposites can be designed and utilized in real-world applications.

Learning Outcomes (LO):
- Students will get to know the various types of composite materials.
- Students will get to know the techniques of fabrication of macro-composites and nanocomposites.
- Students will get to know the various methods for processing of nanocomposites.
- Students will get to know the properties and characterization of nanocomposites and various industrial applications.

Course Outline:

Unit 1: Composite materials and nanocomposites: -definition and classification. Introduction to hybrid nanostructures - fabrication methods. Fabrication methods of nanocomposites - ceramic - metal nanocomposites, ceramic based nanoporous composites, metal matrix nanocomposites, polymer-based nanocomposites, carbon nanotube based nanocomposites and natural nano-bio composites. Template synthesis, homogeneous/heterogeneous nucleation, binding mechanisms. Morphology and fractal model of hybrid nanocomposites, Langmuir-Blodgett metallo-polymer films as self-organized hybrid nanocomposites. Infiltration techniques, stir mixing, extrusion method, exfoliation & intercalation, solution casting method, impregnation techniques - hot melt impregnation, solution impregnation.

Unit 2: Biomimetic nanocomposites and biologically inspired nanocomposites. Properties and various testing techniques - mechanical properties, stress - strain relationship, toughness/hardness, strength, plasticity. Types of indentation - Oliver & Pharr, Vickers indentation process, nano indentation by AFM, rheology of nanocomposite matrix.

Unit 3: Industrial applications: - hybrid materials and nanocomposite. Application in corrosion protection, regeneration of bones by using bio compatible ceramics, hard coatings, DLC coatings. Biologically inspired nanocomposites - synthetic nanocomposites for bone & teeth replacement. Nanocomposites in sensors, and catalysis.
Nanocomposites in aerospace and defense industry. Conventional materials vs nanocomposites. High temperature polymers - aromatic liquid crystalline polyesters, phenolics, polyimide, poly ether ketones synthesis, processing and applications. Materials for cryogenic applications - metals for low temperature applications, austenitic stainless steel, nitrogen containing steel, aluminum-lithium alloys, titanium alloys, cryo insulation materials, polymers and adhesive for cryo-temperature applications. Materials for space environment - radiation shielding materials, atmospheric oxygen resistant materials, space suit and bullet proof materials, materials for life support systems. Nanocomposites in paint industry and energy applications.

Text Books and References:

1. ‘Introduction to Nano Technology’ by Charles. P. Poole Jr and Frank J. Wiley-Interscience 2008.
2. ‘Introduction to Nanocomposite Materials: Properties, Processing, Characterization’ by Thomas E. Twardowski DEStech Publications, Inc 2007.
3. ‘Nanocomposite Science and Technology’ by Pulickel M. Ajayan, Linda S. Schadler , Paul V. Braun, Wiley 2006.
4. ‘Encyclopaedia of Nano Technology’ by M. Balakrishna Rao and K. Krishna Reddy (Vol I to X) Campus books.
5. ‘Nanobiotechnology II’ More Concepts and Applications’ by Chad A. Mirkin and Christof M. Niemeyer (Ed), John Wiley & Sons, 2007.
6. ‘Handbook of Biomineralization: Biomimetic and Bioinspired, Chemistry’ by Peter Behrens, Edmund Bäuerlein (Ed), Wiley-VCH; 1st edition 2009).
7. ‘Carbon-Carbon Composites’ by G. Savage, Chapman and Hall 1993.
8. ‘Cellular Ceramics, Structure, Manufacturing, properties and Applications’ by M. Scheffler, P. Colombo, Wiley-VCH 2005.
9. ‘Principles of Ceramic Processing’ by J. S. Reed, Wiley 2nd edition 1995.
10. ‘High Performance Materials in Aerospace’ by H. M. Flower, Springer Science & Business Media 5th edition 2012.
11. ‘Advanced Aerospace Materials’ by Horst Buhl, B. Ilschner, K. C. Russel, Springer 1992.
12. ‘Specialty Polymers: Materials and Applications’ by Faiz Mohammad, I. K. International publishing House Pvt. Ltd. 2013.

	Semester: II	
Course Name: Nanotechnology in Energy and Environment		**Course Code: NTTE-560**
Course type: DSE		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:
To provide the students with the knowledge of synthesis, properties, and applications of composite and nanocomposite materials, so that they would be able to understand their industrial use.

Prerequisites:

A strong foundation in basic sciences such as physics, chemistry, and biology is essential to understand the principles and concepts of nanotechnology and its applications in energy and environment.
Knowledge of material science and engineering concepts, including the properties and behavior of materials at the nanoscale, is relevant to understanding the unique characteristics of nanomaterials.
Familiarity with environmental science concepts and issues is useful in understanding the role of nanotechnology in addressing environmental challenges.

Learning Outcomes (LO):

- Students will get to understand the fundamentals of nanotechnology.
- Students will explore energy-related nanomaterials.
- Students will analyze environmental applications of nanotechnology.
- Students will evaluate nanotechnology-enabled energy efficiency and investigate nanoscale energy conversion processes.
- Students will learn interdisciplinary nature of nanotechnology in energy and environmental fields and collaborate effectively with professionals from different scientific backgrounds.

Course Outline:

Unit 1: Nanomaterials for Renewable Energy Technologies: Introduction to nanotechnology in renewable energy, Nanoscale behavior of light-matter interactions. Nanomaterials for photovoltaic solar cells and their efficiency improvements. Role of nanotechnology in enhancing energy conversion efficiency. Nanomaterials for fuel cells and energy storage devices. Semiconductor nanoparticles in energy harvesting. Nanomaterials for thermoelectric energy conversion. Nanotechnology-enabled advances in energy-efficient lighting.

Unit 2: Nanotechnology for Environmental Remediation: Introduction to nanotechnology in environmental applications. Nanomaterials for water purification and pollutant removal. Role of nanoparticles in contaminant detection and sensing. Nanotechnology in air and soil pollution control. Nanomaterials for catalytic environmental remediation. Nanotechnology in wastewater treatment. Nanoscale adsorbents for heavy metal removal. Nanoparticles for sustainable agriculture and soil improvement.

Unit 3: Nanotechnology and Sustainable Solutions: Nanotechnology in sustainable energy and green technologies. Nanomaterials for energy-efficient buildings and construction. Role of nanotechnology in sustainable transportation. Nanotechnology in carbon capture and utilization. Nanomaterials for sustainable packaging and waste management. Nanotechnology for environmental monitoring and risk assessment. Ethical considerations in nanotechnology for energy and environmental applications. Future prospects and innovations in nanotechnology for sustainability.

Text Books and References:

1) Nanotechnology for Energy and Environmental Engineering by Lalita Ledwani, Springer
2) Advancements in Nanotechnology for Energy and Environment by Hakan F. Öztop, Springer
3) Nanomaterials for Sustainable Energy and Environmental Remediation by Raju Kumar, Springer
4) Nanotechnology and Energy by Vincent Kaufui Wong, Jenny Stanford Publishing

Semester : II		
Course Name: On the Job Training		**Course Code:MNTOJT-561**
Course type :-		**8 Hrs/ Week**
Total contact hours :120 Hrs	**Lab. Work Credit:** 4	**Marks** :100
	Learning outcomes: On completion of this course, the students will be able:	
1.		
2.		
3.		

Semester : II		
Course Name: Field Project		**Course Code: MNTFP-561**
Course type :- --		**8 Hrs/ Week**
Total contact hours :120 Hrs	**Lab. Work Credit:** 4	**Marks** :100
	Learning outcomes: On completion of this course, the students will be able:	
1.		
2.		
3.		
4.		

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