MTech in Nano Science and Technology

Semester- I

APPLIED MATHEMATICS			
Course Code	22NST11	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

1. To impart knowledge of various numerical methods to solve the problems
2. To understand advanced linear algebra and numerical/statistical methods used in chemical engineering practice.
3. To learn mathematical/optimization techniques required to get an insight in various nanomaterials application.

Module-1

Ordinary and Partial Differential Equations

Simultaneous first order linear equations with constant coefficients – linear equations of second order with constant and variable coefficients – Formation of partial differential equations – Classification of second order partial differential equations

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Solution of Systems of Linear Equations:

Partition method, Croute's Triangularisation method. Eigen values and Eigen vectors. Bounds on Eigen Values. Jacobi method for symmetric matrices.

Teaching-Learning Process	.Chalk and talk method / PowerPoint Presentation

Module-3

Ortoganality and Least Squarers

Orthogonal vectors, orthogonal bases, orthonormal sets, orthogonal projection, QR factorization. Gram-Schmidt orthogonalization process and Applications to linear models- Least squares lines.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Probability Theory

Probability: Random variables, Probability distributions: Binomial, Poisson, Normal distributions, Joint probability distribution (discrete)- examples.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5

Sampling Theory

Sampling distributions - Tests based on t-distribution, chi-square and F-distributions - Analysis of variance - One-way and two-way classifications.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks**or**oneSkill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Books

1. Sankara Rao K, "Introduction to Partial Differential Equations", PHI, New Delhi, 2003.
2. David C. Lay, Steven R. Lay and J. J. McDonald: Linear Algebra and its Applications, 5th Edition, Pearson Education Ltd., 2015.
3. M K Jain, S.R.K Iyengar, R K. Jain, Numerical Methods for Scientific and Engg. Computation, New Age International, 2003.
4. Gupta. S.C, and Kapoor. V.K, "Fundamentals of Mathematical Statistics", Sultan Chand and Sons, New Delhi, 1999.
5. Kapoor. V.K, "Statistics (Problems and Solutions)", Sultan Chand and Sons, New Delhi, 1994.

Web links and Video Lectures (e-Resources):

- Ordinary and Partial Differential Equations, Prof. P. N. Agrawal, Dr. D.N. Pandey, IIT Roorkey : https://www.youtube.com/watch?v=Kk5SEzASkZU
- Linear Equations, Dr. K.C. Sivakumar, IIT Madras: https://www.youtube.com/watch?v=1LubzKrjr68
- Ortoganality and Least Squarers: https://www.youtube.com/watch?v=-GdrMuXF8uw
- Probability Theory, Dr. S. Dharmaraja, IIT Delhi: https://archive.nptel.ac.in/courses/111/102/111102160/

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Explain basic concepts will enable the students to apply mathematical models for solving problems in nanotechnology.	Understand
CO2	Solve system of linear equations using direct and iterative methods.	Apply
CO3	Apply the technique of least square approximation in solving inconsistent linear systems.	Apply
CO4	Describe the basic notions of discrete and continuous probability distributions.	Remember
CO5	Carry out responses of linear systems using statistical and probability tools.	Apply
CO6	Demonstrate a systematic knowledge of the mathematics for Nanotechnology applications.	Apply

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Modern tool usage	5
5	Project management and finance	11

Mapping of COS and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	x				x						x	
CO2	x	x			x						x	
CO3	x	x			x						x	
CO4	x				x						x	
CO5	x	x			x						x	
CO6	x	x	x		x						x	

NANOMATERIALS SYNTHESIS AND PROCESSING			
Course Code	**22NST12**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:2:0	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory + 10-12 Lab slots	Total Marks	100
Credits	4	Exam Hours	3

Course objectives:

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

MODULE-1

Physical Methods:

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

MODULE-2

Chemical methods: Principle and applications

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

MODULE-3

Combustion and Solution Methods: Principle and applications

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

MODULE-4

Biological methods: Principle and applications

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

MODULE 5

Surface Modification of Nanoparticles

Introduction to Nanoparticles dispersion and aggregation behaviour, Surface interaction between nanoparticles, Difficulty in nanoparticle control based on DLVO theory. Effect of particle diameter and solid fraction on distance between the particle surface, Surface molecular level structure of Nanoparticles. Basic approach to

control nanoparticle dispersion behaviour. Surface modification of inorganic nanoparticles by organic functional groups –Organic modification of Metal, Metal oxide nanoparticles, hybridization of inorganic nanoparticles with biomolecules. Surface modification of Carbon Nanostructures.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

PRACTICAL COMPONENT OF IPCC

Sl.NO	Experiments
1	Synthesis of silver nanoparticles by reduction method using plant extracts
2	Synthesis of gold nanoparticles by Chemical reduction method
3	Synthesis of ZnO nanoparticles by hydrothermal method
4	Synthesis of TiO_2 nanoparticles by Solvothermal method
5	Synthesis of ceramic $BaTiO_3$ nanomaterial by combustion process
6	Synthesis of ceramic $SrTiO_3$ nanomaterial by Sol-Gel method
7	Surface functionalization or modification of Al_2O_3 metal oxide nanoparticles with organic reagents
8	Synthesis of Fe_2O_3/Mn_3O_4 nanoparticles by Co-precipitation method
9	Surface functionalization or modification of Fe_2O_3 metal oxide nanoparticles with organic reagents
10	Synthesis of ZnS/MoS nanoparticles by microwave Solvothermal method
11	**Demo experiment: Synthesis of carbon nanotubes by CVD**
12	**Demo experiments: Synthesis of nanoparticles by SCF method**

Assessment Details (both CIE and SEE)

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

CIE for the theory component of IPCC

1. Two Tests each of **20 Marks**
2. Two assignments each of **10 Marks/One Skill Development Activity of 20 marks**
3. Total Marks of two tests and two assignments/one Skill Development Activity added will be CIE for 60 marks, marks scored will be proportionally scaled down to **30 marks**.

CIE for the practical component of IPCC

- On completion of every experiment/program in the laboratory, the students shall be evaluated and marks shall be awarded on the same day. The**15 marks** are for conducting the experiment and preparation of the laboratory record, the other **05 marks shall be for the test** conducted at the end of the semester.
- The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to 15 marks.
- The laboratory test at the end /after completion of all the experiments shall be conducted for 50 marks and scaled down to 05 marks**.**

Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **20 marks**.

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SEE for IPCC

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (duration 03 hours)

1. The question paper will be set for 100 marks and marks scored will be scaled down proportionately to 50 marks.
2. The question paper will have ten questions. Each question is set for 20 marks.
3. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.
4. The students have to answer 5 full questions, selecting one full question from each module.

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper shall include questions from the practical component).

- The minimum marks to be secured in CIE to appear for SEE shall be the 15 (50% of maximum marks-30) in the theory component and 10 (50% of maximum marks -20) in the practical component. The laboratory component of the IPCC shall be for CIE only. However, in SEE, the questions from the laboratory component shall be included**.** The maximum of 04/05 questions to be set from the practical component of IPCC, the total marks of all questions should not be more than the 20 marks.
- SEE will be conducted for 100 marks and students shall secure 40% of the maximum marks to qualify in the SEE. Marks secured will be scaled down to 50. (Student has to secure an aggregate of 50% of maximum marks of the course(CIE+SEE)

Suggested Learning Resources:

TEXT BOOKS:

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

References:

1. Nanomaterials – A. K. Bandyopadhyay, New Age International Publishers, 2nd Edition, 2010
2. T. Pradeep , "NANO The Essential , understanding Nanoscience and Nanotechnology". Tata McGraw-Hill Publishing Company Limited, 2007.
3. C.A. Mirkin and C.M. Niemeyer, Nanobiotechnology- II, More Concepts and Applications, WILEY-VCH, VerlagGmbH&Co, 2007.

Additional Readings:

1. Hari Singh Nalwa - Encyclopedia of Nanotechnology.
2. Processing & properties of structural Naonmaterials by Leon L. Shaw (editor)
3. Chemistry of Nanomaterials : Synthesis, properties and applications by CNR Rao et.al.
4. Nanochemistry: A chemical approach to Nanomaterials Roayal Society of Chemistry, Ozin and Arsenault, Cambridge UK 2005,
5. Nanoparticles: From Theory to Applications, G.Schmidt, Wiley Weinheim 2004.

Web links and Video Lectures (e-Resources):

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

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

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

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

Program Outcome of this course

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

Mapping of COS and POs

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

QUANTUM MECHANICS AND ELECTROMAGNETIC THEORY			
Course Code	**22NST13**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	50
Total Hours of Pedagogy	50	Total Marks	100
Credits	4	Exam Hours	3

Course Learning objectives:

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

Module-1

Introduction

Introduction to Quantum Mechanics

Limitation of Mechanics at the Nanoscale - Success of Quantum Mechanics – Wave- particle Duality – Quantum mechanics of a free particle confined to 1 and 3-dimensional box. Quantum mechanics of a free particle confined to a spherical trap (Polar coordinates). Electron in a periodic potential – Bloch Theorem.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Approximation methods: Time Independent Perturbation Theory - Degenerate and Non-generate case.

Identical Particles: Schrodinger equation– Interchange symmetry. Systems of Identical particles (Classical and Quantum View) – Experiment on Indintinguishability– Exchange degeneracy - Constructing symmetric and antisymmetric functions (wave functions of two-, three-, and many-particle systems).

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-3

Transport in nanostructures

Nanostructures connected to electron reservoirs - Current density and transmission of electron waves - The current density J - Tunneling through a potential barrier – Reflection and transmission coefficients - Tunnelling in field emission guns – Electron wavefunctions in Semiconductor Nanocrystals: Brus relation using a Particle in a Box model.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Quantum mechanics of Atoms and Molecules

Hamiltonian and Wave functions for Many-particle systems –Multi electron system – Orbital approximation for multielectron atoms – He atom - Pauli's Anti-symmetry principle – Born – Oppenheimer approximation. Molecular orbital Theory – LCAO - Theory of H_2 molecule – H_+ - Term Symbols.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5	
Review of Electromagnetic Theory Electrodynamics: Maxwell Equations in Vacuum and Matter-Importance of Maxwell equations. Continuity Equation - Importance. Poynting Theorem-Energy distribution in EM waves. Electromagnetic waves in Vacuum and Matter. Reflection and Transmission at Normal and Oblique Incidences, Complex Refractive Index and Dispersion relation.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Books

1. Quantum Mechanics: Concepts and Applications, Nouredine Zettili, Wiley, New York, (2001), ISBN 0-471 48943 3.

2. Molecular Quantum Mechanics (3rd Edition), P.W. Atkins and R. S. Friedman, Oxford University Press, (2004), ISBN: 0-19-566751-4.

3. Introduction to nanotechnology, Henrik Brus, (2004) MIC – Department of Micro and Nanotechnology, Technical University of Denmark.

4. Semiconductor Nanocrystals: A Powerful Visual Aid for Introducing the Particle in a Box, Tadd Kippeny, Laura A. Swafford, and Sandra J. Rosenthal, J. Chemical Education, Vol. 79(9), 2002, 1094-1100.

5. Introduction to Electrodynamics, David J. Griffiths, (ISBN: 978-81-203-1601-0), Prentice-Hall, India, (2009).

6. Quantum Mechanics, Vol I and Vol II, Claude Cohen-Tannaoudji, Bernard Diu, Franck Laloe, John

Wiley & Sons (2005).

7. Quantum mechanics, J. L. Powell and B. Craseman, Addison-Wesley (1964).

8. Y T Tan et al. 2003 J. Appl. Phys. 94 633.

9. Classical electromagnetism J. D. Jackson, John Wiley Publications (1999) (ISBN 0- 471-30932-X).
10.Quantum Mechanics for Nanostructures, Vladimir V. Mitin, Dmitry I. Sementsov, Nizami Z. Vagidov. Cambridge University Press 2010.

Web links and Video Lectures (e-Resources):

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

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

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

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

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

Program Outcome of this course

Mapping of COS and POs

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

THERMODYNAMICS AND KINETICS FOR NANOSCIENCE AND TECHNOLOGY			
Course Code	**22NST14**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

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

Module-1	
Thermodynamic laws, Entropy, Statistical thermodynamics: micro-and macro-states. Unitary and multi-component systems, Gibbs phase rule, phase diagrams relevant to macro systems and for nanoscale materials formation, Phase transitions. General criterion for equilibrium-chemical potential and Gibbs free energy.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2	
Statistical Thermodynamics: Concepts of probability and Maxwell Boltzmann distribution. Different ensembles and partition functions. Thermodynamic functions using appropriate partition functions. Fermi-Dirac and Bose-Einstein statistics and statistical basis of entropy. Heat capacity of solids. Debye and Einstein models. Thermodynamic functions of ideal gases, translational, vibrational and rotational contributions at different levels of approximation. Application of statistical thermodynamics concepts to ortho para hydrogen internal rotation - Calculation of equilibrium constants.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-3	
Phase Transformations: Fick's laws of diffusion, solution of Fick's second law and its applications, atomic model of diffusion, Temperature dependence of diffusion coefficient, Kirkendall effect. Thermodynamic considerations: Free energy of alloy phases and free energy-composition curves for binary systems.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4	
Nucleation and growth - energy considerations; heterogeneous nucleation, growth kinetics, overall transformation rates. Solidification: Nucleation and growth from liquid phase, stable interface freezing, cellular and dendrite growth, freezing of ingots, nucleation and grain size, segregation, directional solidification, growth of single crystals.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5	
Precipitation from solid solution: Homogeneous and heterogeneous nucleation of precipitates, the aging curve, mechanisms of age hardening, examples from Al-Cu and other alloy systems. Order-disorder Transformation: Examples of ordered structures, long and short-range order, detection of super lattices, influence of ordering on properties.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module

Suggested Learning Resources:

Books

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

Web links and Video Lectures (e-Resources):

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

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

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

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

Program Outcome of this course

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

Mapping of COS and POs

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

MATERIALS SCIENCE AND PROPERTIES OF NANOMATERIALS			
Course Code	**22NST15**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

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

Module-1

Crystal structures

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Bonding in Nanostructures

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-3

Bonding in Nanostructures

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Electronic Properties

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5	
Mechanical behavior Stress-strain, tensile strength, toughness, micro-hardness, wear resistance, corrosion resistance behaviors of nanomaterials. **Thermal properties:** Heat capacity, thermal conductivity and thermal expansion of nanomaterials. **Magnetic properties:** Fundamentals of magnetism - Different kinds of magnetic materials: dia, para, ferro, ferri and anti-ferromagnetic materials - Magnetic hysteresis – Superparamagnetism – Important properties in relation to Nano-magnetism.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

TEXT BOOKS:

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

12. Understanding Solids: The Science of Materials, Tilley, Richard J. D. John Wiley & Sons,2004V.Ragavan, Materials Science and Engg., Prentice-Hall of India(p) Ltd, New Delhi.
13. Nanostructured Materials, Edited by Carl C. Koch, Noyes Publications, New York, 2002.

Web links and Video Lectures (e-Resources):

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

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

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

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

Program Outcome of this course

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

Mapping of COS and POs

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

SYNTHESIS AND PROPERTY MEASUREMENT LAB			
Course Code	**22NSTL17**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	1:0:2	SEE Marks	50
Credits	2	Exam Hours	3

Course objectives:

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

Sl.NO	Experiments
1	Verification of Beer Lombard's Law
2	Synthesis of gold nanoparticles by Chemical reduction method
3	Synthesis of ZnO nanoparticles by hydrothermal method
4	Synthesis of TiO_2 nanoparticles by Solvothermal method
5	Synthesis of ceramic $BaTiO_3$ nanomaterial by combustion process
6	Synthesis of ceramic $SrTiO_3$ nanomaterial by Sol-Gel method
7	Photocatalytic degradation property analysis of TiO_2 nanoparticles
8	Preparation of cadmium sulphide nanoclusters and its spectral studies
9	Synthesis of silver nanoparticles by reduction method using plant extracts
10	Fabrication of thin films using Spin coating technique

Course outcomes (Course Skill Set):

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

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

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation (CIE):

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

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

- Each experiment to be evaluated for conduction with observation sheet and record write-up. Rubrics for the evaluation of the journal/write-up for hardware/software experiments designed by the faculty who is handling the laboratory session and is made known to students at the beginning of the practical session.
- Record should contain all the specified experiments in the syllabus and each experiment write-up will be evaluated for 10 marks.
- Total marks scored by the students are scaled downed to 30 marks (60% of maximum marks).
- Weightage to be given for neatness and submission of record/write-up on time.
- Department shall conduct 02 tests for 100 marks, the first test shall be conducted after the 8th week of the

semester and the second test shall be conducted after the 14th week of the semester.

- In each test, test write-up, conduction of experiment, acceptable result, and procedural knowledge will carry a weightage of 60% and the rest 40% for viva-voce.
- The suitable rubrics can be designed to evaluate each student's performance and learning ability.
- The average of 02 tests is scaled down to **20 marks** (40% of the maximum marks).

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

Semester End Evaluation (SEE):

SEE marks for the practical course is 50 Marks.

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

All laboratory experiments are to be included for practical examination.

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

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

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

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

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

The duration of SEE is 03 hours

Suggested Learning Resources:

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

Semester- 2

DESIGN AND FABRICATION TECHNIQUES			
Course Code	**22NST21**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

- The learning objectives of the course are to provide students with the knowledge of miniaturization concept and Quantum mechanical aspects.
- Understand the principles of Nanofabrication process; determine the suitability of nanostructures for fabrication of devices.
- The course provides a strong theoretical and analytical understanding of nanostructures and devices fabrication process for its applications.

Module-1

The Science of Miniaturization

Miniaturization of Electrical and Electronic Devices, Moore's law and technology road map, Quantum Mechanical Aspects, Simulation of the Properties of Molecular Clusters, Formation of the Energy Gap, Confinement Effects, Discreteness of Energy Levels, Tunnelling Currents.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Nanofabrication by Photons

Principles of Optical Projection Lithography, Process of Optical Lithography. Photoresists Characteristics. Optical Lithography at Shorter Wavelengths-Deep UV, Extreme UV and X-ray Lithography. Optical Lithography at High Numerical aperture, Near-Field Optical Lithography.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-3

Nanofabrication by Ion Beam

Introduction, Liquid Metal Ion Sources, Focused Ion Beam Systems, Ion Scattering in Solid Materials , FIB Direct Nanofabrication , Ion Sputtering, Ion Beam Assisted Deposition, Applications, Focused Ion Beam Lithography, Ion Projection Lithography.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Nanofabrication by Scanning Probes

Introduction, Principles of Scanning Probe Microscopes, Exposure of Resists- Exposure of Resist by STM, Exposure of Resist by NSOM, Additive Nanofabrication, Field Induced Deposition, Dip-Pen Nanolithography, Subtractive Nanofabrication-Electrochemical Etching, Field Induced Decomposition, Thermomechanical Indentation, Mechanical Scratching, High Throughput Scanning Probe Lithography.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5

Fabrication of micro/nano devices

Microfluidic Devices - Microchannels, Microfilters, Micro- valves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Lithium Ion Battery and Super capacitors device fabrication, Operating and structure of Solar cells-CIGS solar cells, Dye-Sensitized solar cells, and Perovskite solar cell. MEMS and NEMS based devices`

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module

Suggested Learning Resources:

TEXT BOOKS:

1. Guozhong Cao, Nanostructures & Nanomaterials Synthesis, Properties G; Z: Applications, World Scientific Publishing Private, Ltd., Singapore (2004).
2. W.R.Fahrner, Nanotechnology and Nanoelectronics – Materials, Devices, Measurement Techniques, SpringerVerlag Berlin, Germany (2006).
3. R. H. J. Hannink and A. J. Hill, Nanostructure control of materials, Woodhead Publishing Limited and CRC Press LLC, Cambridge, England (2006).
4. Zheng Cui, Nanofabrication, Principles, Capabilities and Limits, Springer Science + business media, New York (2008).

References:

1. Hari Singh Nalwa, Handbook of Nanostructured Materials and Nanotechnology (Vol. 3)- Electrical Properties, Academic Press, San Diego, USA (2000).
2. Huff, Howard, Into The Nano Era: Moore's Law Beyond Planar Silicon CMOS (Vol. 106), Springer Series in Materials Science, Springer-Verlag Berlin (2009).
3. Marc J. Madou, Fundamentals of Microfabrication: The Science of Miniaturization, 2nd Edition, CRC Press, California, USA (2002).
4. Kostya (Ken) Ostrikov and Shuyan Xu, Plasma-Aided Nanofabrication: From Plasma Sources to Nanoassembly, WILEY-VCH Verlag GmbH & Co. KGaA (Weinheim) (2007).

Web links and Video Lectures (e-Resources):

- Nanomaterials Science and Nanomanufacturing: Dr. Kantesh Balani & Dr. Anandh Subramaniam, IIT Kanpur: https://www.youtube.com/watch?v=rDJOzKRGJm8
- Lithography: Prof. A.K. Ganguli, IIT Delhi: https://www.youtube.com/watch?v=ugif3s7a6h8
- Focused Ion beam machining: https://www.youtube.com/watch?v=pWYHVsu7Fhk
- Overview of Scanning Probe Lithography: https://www.youtube.com/watch?v=MshGAYYNZ8o

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Understand and appreciate the importance of nanostructure and its impact device fabrication	Understand
CO2	Differentiate between nanofabrication process and understand the advantages and limitations of process for device fabrication	Analyze
CO3	Explain the miniaturization of devices to Nano devices, process challenges and analyse theory for emerging Nano scale devices	Understand
CO4	Evaluate the advances in Nano scale technology and device fabrication their application in electronics, sensors, biomedical and energy generation and storage.	Evaluate

Program Outcome of this course

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

Mapping of COS and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	x											
CO2	x	x	x	x	x							
CO3	x											
CO4	x	x	x	x	x	x	x	x				x

ANALYTICAL METHODS FOR CHARACTERISATION OF NANOMATERIALS			
Course Code	**22NST22**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:2:0	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory + 10-12 Lab slots	Total Marks	100
Credits	4	Exam Hours	3

Course objectives:

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

MODULE-1

X-Ray based characterization

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

MODULE-2

Electron microscopy techniques

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

MODULE-3

Spectroscopic techniques

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

MODULE-4

Magnetic characterization

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

MODULE 5

Electrical measurements

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

PRACTICAL COMPONENT OF IPCC *(May cover all / major modules)*

Sl.NO	Experiments
1	Surface functional group identification of nanoparticles by FTIR measurement
2	Calculation of d-spacing and crystallite size of Nanomaterials from X- ray diffraction data
3	Crystal structure identification by X-ray diffraction studies
4	Crystallite Size Calculation of nanoparticles using X-ray diffraction pattern
5	UV-Visible absorption studies of metal nanoparticles
6	Recording optical absorption spectra of nanoparticles and their band gap estimation from the band edge
7	Impedance measurement of nanomaterial
8	Curie temperature determination of nanomaterial
9	Demo experiment: Cyclic voltamertic measurement of nanomaterial
10	Demo experiment: Magnetic property measurement of nanomaterial

Assessment Details (both CIE and SEE)

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

CIE for the theory component of IPCC

1. Two Tests each of **20 Marks**
2. Two assignments each of **10 Marks/One Skill Development Activity of 20 marks**
3. Total Marks of two tests and two assignments/one Skill Development Activity added will be CIE for 60 marks, marks scored will be proportionally scaled down to **30 marks**.

CIE for the practical component of IPCC

- On completion of every experiment/program in the laboratory, the students shall be evaluated and marks shall be awarded on the same day. The**15 marks** are for conducting the experiment and preparation of the laboratory record, the other **05 marks shall be for the test** conducted at the end of the semester.
- The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to 15 marks.
- The laboratory test at the end /after completion of all the experiments shall be conducted for 50 marks and scaled down to 05 marks**.**

Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **20 marks**.

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SEE for IPCC

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (duration 03 hours)

1. The question paper will be set for 100 marks and marks scored will be scaled down proportionately to 50 marks.
2. The question paper will have ten questions. Each question is set for 20 marks.
3. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.
4. The students have to answer 5 full questions, selecting one full question from each module.

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper shall include questions from the practical component).

- The minimum marks to be secured in CIE to appear for SEE shall be the 15 (50% of maximum marks-30) in the theory component and 10 (50% of maximum marks -20) in the practical component. The laboratory component of the IPCC shall be for CIE only. However, in SEE, the questions from the laboratory component shall be included**.** The maximum of 04/05 questions to be set from the practical component of IPCC, the total marks of all questions should not be more than the 20 marks.
- SEE will be conducted for 100 marks and students shall secure 40% of the maximum marks to qualify in the SEE. Marks secured will be scaled down to 50. (Student has to secure an aggregate of 50% of maximum marks of the course(CIE+SEE)

Suggested Learning Resources:

TEXT BOOKS:

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

References:

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

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

Web links and Video Lectures (e-Resources):

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

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

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

Program Outcome of this course

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

Mapping of COS and POs

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

NANO BIOTECHNOLOGY			
Course Code	**22NST231**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

- To provide fundamental aspects of biotechnology.
- To understand the interaction of nanostructures and biomolecules
- To learn to use various nanomaterials in biological application.

Module-1

Fundamentals of Biotechnology

Basic terms in biotechnology, recombinant DNA technology, genetic engineering, gene cloning. Development of nanobiotechnology, timelines and progress. Basics of cell orgenells. Biomacromolecules-carbohydrates, lipids, proteins and nucleic acids, PHA, cyanophcin inclusion, magnetosome, alginates, bacteriophages, S-layer protein, bacteriorhodpsin. Biological building blocks; Sizes of building blocks and comparison with nanostructures.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Nanostructures:

DNA and protein based nanostructures, DNA origami, DNA nanotubes, polypeptide nanowire and protein nanoparticles, SAM, biological nanomotor. Nanoconjugates: DNA-gold nanoconjugates. DNA based nanoelectronics: immobilization of DNA on substrates, probing the electronic properties of single DNA molecules. Manipulation of DNA on metal surfaces.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-3

Interaction between biomolecules and nanoparticle surface

Different types of inorganic materials used for the synthesis of hybrid nano-bio assemblies, Application of nano in biology, nanoprobes for Analytical Applications - A new methodology in medical diagnostics and Biotechnology, Current status of Nanobiotechnology, Future perspectives of Nanobiology.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Applications of nanomaterials

Drug delivery and gene delivery, Nanobiochips, biosensors. Nanomaterials in bone substitutes and dentistry. Polymeric nanofibres-tissue engineering, smart capsules, microemulsions, nano based cancer therapy, nanorobotics. Lotus leaf as a model self-cleansing system. Diatoms as example for silicon biomineralization. Biomechanical strength properties of Spider silk.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5

Photoinduced Electron Transport in DNA

Electronic Devices Based on DNA Architecture, DNA Nanowires, Charge Transport, DNA-Based Nanoelectronics, Electrical Manipulation of DNA on Metal Surfaces, Nanostructured Bio-compartments, DNA-Gold nanoconjugates.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

TEXT BOOKS:

1. Nanobiotechnology: Bioinspired devices and materials of the future by OdedShoseyov, Ilan Levy. Humana Press 2010.
2. Bionanotechnology - Global Prospects by David E. Reisner, Taylor & Francis Group, LLC, 2009.
3. Nanotechnology in Drug Delivery by Melgardt M.deVilliers, PornanongAramwit, Glen S. Kwon, Springer-American Association of Pharmaceutical Scientists Press 2009.

References:

1. T. Pradeep , "NANO The Essential , understanding Nanoscience and Nanotechnology". Tata McGraw-Hill Publishing Company Limited, 2007.

2. Nancy A. Monteiro-Riviere, C. Lang Tran Nanotoxicology: Characterization, Dosing and Health Effects Published:July 25, 2007 by CRC Press

Web links and Video Lectures (e-Resources):

- Fundamental of Biology & Biotechnology: Dr. Rintu Banerjee, IIT Kharagpur: https://www.youtube.com/watch?v=m_Xrh5uJFJo
- DNA Nanotechnology: https://www.youtube.com/watch?v=ZQf7ewZGZXg
- Nanomaterials for Cancer Therapy: Prof. P. Gopinath, IIT Roorkee: https://terna.digimat.in/nptel/courses/video/102107058/L12.html
- Nanomedicine & Drug delivery: IIT Bombay: https://www.youtube.com/watch?v=oYGfoj18izA

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Demonstrate knowledge of biotechnology to understand Nanobiotechnology.	Apply
CO2	Analyze the interaction of various biomolecules and nanostructures.	Analyze
CO3	Design and develop nanostructures and biomolecules for various biological applications.	Create

Program Outcome of this course

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

Mapping of COS and POs

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

NANO MATERIALS AND TECHNOLOGY FOR ENVIRONMENT			
Course Code	**22NST232**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

- To learn applications of different nanomaterials for Environmental remedies, removal of pollutant from exhaust gases.
- Understand the effect of nanoparticle on health and environment and their toxicology.
- To introduce controlled environment, types of cleanrooms and their importance.

Module-1

Environmental Application of Nanomaterials

Metal oxide nanoparticles organic contamination remediation, Nano active materials, Advanced photocatalyst, removal organic contamination from waste water using Nanomaterials based photocatalyst. Nanostructure electrode for Electrochemical oxidation.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Nanostructured catalytic materials

Nanostructured metals like Pt, Pd and Fe, nanostructured ceramics like silica, silicate and alumina, pillared clays, colloids and porous materials. Nanomaterials as catalyst for exhaust gas treatment such as CO_2, H_2S, Pb, NO.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-3

Nanomaterials as Adsorbents

Meosoporous materials-synthesis and characterization, properties and application with suitable examples, unipore size, bimodal pore size. Nanoporous materials- synthesis and application. Adsorption at the Oxide Nanoparticles/Solution Interface, Nanomaterial-Based Removal of nanoparticles-Principle of particle removal - Removal of nanoparticles suspended in gas - Removal of nanoparticles in liquid. Adsorption of hazardous chemicals by metal oxide nanoparticles, Adsorption of chemical warfare agents by metal oxide nanoparticles. Nanomaterials as adsorbents for Heavy metal removal from water and Wastewater Treatment, Nanomaterials for Groundwater Remediation- Reactivity, Fate, and Lifetime Delivery and Transport Issues.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Nanotoxicology

Health effects on nanoparticles - Inhalation of nanomaterials–overview, Nanoparticle exposure and systematic cardiovascular effects. Respiratory particulate matter exposure and cardiovascular toxicity, Toxicity of different nanomaterials, Toxicological assessment of nanoparticles: Toxicity of polymeric nanoparticles. Eco-toxicological Impacts of Nanomaterials. Nanoparticles in atmospheric environment, Ground water environments, Waste water and in exhaust gases - Industrial processes and nanoparticles. Safety of nanoparticles- Problems caused by nanoparticles - Safety assessment for the nanoparticles.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5

Cleanroom basics, hazards, and safety

Basics of cleanroom classification and ISO standards, sources of particulate contamination, clean air devices, special construction materials for cleanroom, and surface finishes. The HEPA filters and filtration process in

the clean rooms. Parameters control in cleanrooms: temperature, RH, air volume and velocity, pressurization, and differential pressure. Potential hazards in cleanrooms: Fire, explosions, toxicity, and physical hazards. Cleanroom operational and behavioural requirement. Material handling issues: DI water, solvents, cleaners, ion implantation sources, diffusion sources, photoresists, developers, metals, dielectrics, toxic gases, flammable, corrosive, and packaging materials. Types of cleanroom waste: handling and disposal of chemical, biological, infectious, radioactive, and mixed waste.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

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

Suggested Learning Resources:

TEXT BOOKS:

1. Glen E. Fryxell, Guozhong Cao, Environmental Applications of Nanomaterials: Synthesis, Sorbents and Sensors
2. Mark R. Wiesner, Jean-Yves Bottero, Environmental Nanotechnology: Applications and Impacts of Nanomaterials
3. J. B Park, "Biomaterials Science and Engineering", Plenum Press, New York, 1984.
4. P.P. Simeonova, N. Opopol and M.I. Luster, "Nanotechnology - Toxicological Issues and Environmental Safety", Springer 2006.

References:

1. J.J. Davis, Dekker, "Encyclopedia of Nanoscience and nanotechnology".
2. Dracy J. Gentleman, Nano and Environment: Boon or Bane? Environmental Science and technology, 43 (5), P1239, 2009
3. Vinod Labhasetwar and Diandra L. Leslie, "Biomedical Applications of nanotechnology", A John Willy & Son Inc, N.J, USA, 2007.
4. Cleanroom Technology: Fundamentals of Design, Testing, and Operation by William White, Print ISBN 0-471-86842-6, John Wiley & Sons Ltd, 2001
5. Hazardous Waste Management by Michael D. LaGrega, Reissue edition, ISBN-13: 978-1577666936, Waveland Press Inc., 2010

Web links and Video Lectures (e-Resources):

- Magnetic Nanocomposite for Wastewater Treatmen: https://www.youtube.com/watch?v=M3lXWqlw1DA
- Introduction to catalysts and catalysis: Prof. A.K. Suresh,Prof. Sanjay M. Mahajani & Prof. Ganesh A. Viswanathan, IIT Bombay: https://www.youtube.com/watch?v=jeUW6h2oVEY
- Photocatalysis: Prof. A.K. Ganguli,IIT Delhi: https://www.youtube.com/watch?v=yFdDdcJfncY
- Adsorption and Ion Exchange: IIT Kharagpur: https://www.youtube.com/watch?v=_LSKHSQmwwE
- Cleanroom Training Video: https://www.youtube.com/watch?v=Um0VA6iycY4

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Apply nanomaterials in different environmental applications.	Apply
CO2	Demonstrate knowledge about the nanoparticles effect on health and safety issues.	Apply
CO3	Understand Nanoparticles toxicity and their effect on health.	Understand
CO4	Understand Importance of clean rooms and their usage.	Understand

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5
6	The engineer and society	6
7	Environment and sustainability	7
8	Ethics	8
9	Life-long learning	12

Mapping of COS and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	x	x			x			x				x
CO2	x	x	x	x	x	x	x	x				x
CO3	x	x			x			x				x
CO4	x	x			x			x				x

NANOCOMPOSITES AND THEIR APPLICATIONS			
Course Code	**22NST233**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

- To give an overview of Nanocomposites and properties.
- To learn about various nanostructures to be used in designing Nanocomposites.
- To understand the applications Nanocomposites in industry

Module-1

Introduction to nanocomposites

Definition of composite material, Classification based on matrix and topology, Constituents of composites, Interfaces and Interphases, Distribution of constituents, Nano-composites. Advantage of composite materials, mechanical properties, Thermal, electrical and electronic and optical properties. Super hard nanocomposites-designing and mechanical properties - stress-strain relationship, toughness, strength, and plasticity.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Ceramic metal nanocompsites

Ceramic based nanoporous composites, metal matrix nanocomposites, natural nano-bioccomposites, bio-mimetic nanocompostes and biologically inspired nanocomposites, nanocompsites for hard coatings, DLC coatings, thin film naocomposites, modelling of nanocomposites, synthesis of various nanocomposites materials, sputtering, mechanical alloying.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-3

Polymer nanocomposites

Introduction to polymer composites, Processing of nanoparticles, binding mechanisms in nanoparticles, dispersion of nanoparticles, and stabilization of nanoparticles. Processing and fabrication of polymer nanocomposites, Melt blending, solvent casting, In-situ polymerization, solution polymerization, template synthesis, high shear mixing. Homogeneous/heterogeneous nucleation, plasma promoted nucleation. Polymer nanocomposites with structural, gas barrier and flame retardant properties, carbon fibre reinforced polymer composites, elastomer and thermoplastic elastomer nanocomposites for propulsion systems, water borne fire-retardant nanocomposites, hybrid composites for cosmetics, protective and decorative coatings.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Natural nanocomposite systems

Spider silk, bones, shells; organic–inorganic nanocomposite formation through self-assembly. Biomimetic synthesis of nanocomposite material; use of synthetic nanocomposites for bone teeth replacement. Bioactive nanocomposites in bone grafting and tissue engineering, inorganic/polymer nanocomposites for dental restoration and bone replacement applications.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5	
Bio ceramics for implant coating Calcium phosphates-hydroxyapatites Ti_6Al_4V and other biomedical alloys, implant tissue interfacing-metal organic CVD-use of tricalcium phosphate-biomimetic and solution based processing- osteoporosis- osteo plastic, regeneration of bones by using bio compatible ceramics, bio interactive hydro gels- PEG coating and surface modifications, PEG hydrogels patterned on surfaces- PEG based hydrogels.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

TEXT BOOKS:

1. Nanocomposite science and technology by P.M.Ajayan, L.S. Schadler and P.V. Braun, Wiley-VCH GmbH Co. 2003.
2. Encyclopedia of Nanotechnology by H.S.Nalwa, American Scientific Publishers, 2003.
3. Metalopolymer nanocomposites, Ed A.D. Pomogailo and V.N.Kestelman, Springer-Verlag, 2005.
4. Composite materials, K.K. Chawala, 2nd ed., (1987) Springer-Verlag, New York.

References:

1. Biomedical nanostructures by Kenneth E.Gonsalves, Craig R. Halberstadt, Cato T. Laurencin, Lakshmi S. Nair. John-Wiley & Sons, 2008.
2. Nanobiotechnology II: Edited by Chad A. Mirkin and Christof M. Niemeyer, Wiley-VCH, 2006.
3. Handbook of Biomineralization: Biomimetic and Bioinspired, Chemistry edited by Peter Behrens, Edmund Bäuerlein John-Wiley Sons, 2006.3. Steven S Saliterman, Fundamentals of BioMEMS and Medical Microdevices, 2006

Web links and Video Lectures (e-Resources):

- Nanocomposites: Prof. A. K. Ganguli, IIT Delhi: https://www.youtube.com/watch?v=t-pVi3IMdOk
- Overview: nanoceramic composites: Prof. B. V. Manoj Kumar, IIT Roorkee: https://www.youtube.com/watch?v=CJn2gXp3pyo
- Polymer Matrix and Nano Composites, Dr. J. Ramkumar, IIT Kanpur: https://www.youtube.com/watch?v=Gtzin_hz9pE
- Introduction to Biomimicry: IITM: https://www.youtube.com/watch?v=Of-sdUpMgsg
- Introduction to Biomaterials, Prof. Bikramjit Basu, IIT Kanpur, Processing of Bioceramics: http://www.infocobuild.com/education/audio-video-courses/materials-science/IntroductionToBiomaterials-IIT-Kanpur/lecture-19.html

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Design different types nanostructures that are suitable to specific application.	Design
CO2	Demonstrate a knowledge of polymer based nanocomposites and its applications.	Apply
CO3	Analyze the properties of polymer Nanocomposites and their behavior depending on the type of nanomaterials.	Apply

Program Outcome of this course

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

Mapping of COS and POs

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

MEMs/NEMs AND MICROSYSTEMS			
Course Code	**22NST234**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

- Learn about basics and typical applications of microsystems
- Illustrate scaling laws & microsensors and microactuators
- Illustrate the various principles of operations of mems transducers
- Learn basic electrostatics and its applications in MEMS sensors and actuators
- Learn about ways to fabricate& a packaging needs MEMS device

Module-1

Mechanics and Materials

Overview of MEMS and Microsystems – Thin film growth and models –Mechanical, Electrical, Thermal properties for Thin Films/MEMS –Measurement techniques – Materials for MEMS- Semiconductors, Metals and Metal alloys, Ceramics, Polymers – Silicon and other substrate materials.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Processing of MEMS/NEMS and Microsystems

Silicon processing, Structure & properties – Single crystal growth - Overview of Lithographic process – Additive processes for Semiconductors, Ceramics, Metals and polymers - MEMS Fabrication – Doping process - Bulk micromachining - Wet & Dry Etching- Isotropic and anisotropic etching and mechanism - Etch stop techniques – DRIE and other processes- Surface Micromachining – LIGA and laser assisted processing – Nanomechanical system fabrication - Fundamentals of Design and Simulation

Teaching-Learning Process	.Chalk and talk method / PowerPoint Presentation

Module-3

Interconnects and Bonding

Interconnects – requirements of interconnects –Metallization Techniques — Damascene process- silicide and refractory metals - Multilevel and nanostructured interconnects – Bonding Techniques.

Packaging and Failure: Packaging Fundamentals – Packaging Techniques– Electrical and thermal requirements - Packaging Reliability and failure modes and analysis – MEMS process integration- Tribological issues

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Engineering Mechanics

Microsystem design – Static bending of thin films –Mechanical vibration– thermomechanics–fracture mechanics – Thermofluidics

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5

Design and Applications

Scaling laws in miniaturization – Design considerations – Process and Mechanical design – Finite element method (FEM), Computer aided design CAD – Mircosensors and Microactuators– Optical, chemical, thermal, gas, pressure, bio and mechanical sensors – Nanosensors–Applications in automobile, aerospace, health care, industrial, consumer and telecommunications

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

3. Three Unit Tests each of **20 Marks**
4. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Books

1. Tai-Ran Hsu, MEMS and Microsystems – Design, Manufacture, and Nanoscale Engineering, Second Edition, John Wiley & Sons, Inc., New Jersey, 2008, ISBN: 978-0-470-08301-7.

2. Reza Ghodssi, Pinyen Lin, MEMS Materials and Processes Handbook, Springer, New York, 2011, ISBN: 978-0-387-47316-1.

3. Nadim Maluf and Kirt Williams, An introduction to Micro electro mechanical systems Engineering, Second Edition – Artech House, Inc., Boston, 2004, ISBN: 1-58053-590-9.

4. Sami Franssila, Introduction to Microfabrication, Second Edition, John Wiley & Sons, Sussex, 2010, ISBN: 978-0-470-74983-8.

5. Marc Madou, Fundamentals of Microfabrication, Second Edition, CRC Press, Boca Raton, 2002, ISBN: 0-8493-0826-7.

6. Francisco J. Arregui, Sensors based on nanostructured materials, First Edition, Springer-Verlag, New York, 2009, ISBN: 978-0-387-77752-8.

7. Bharath Bhushan, Springer Hand Book of Nano Technology, Third Edition, Springer-Verlag, New York, 2010, ISBN: 978-3-642-02524-2.

8. Sergey Edward Lysherski, MEMS and NEMS Systems, devices, and structures, First Edition, CRC Press, Boca Raton, 2002, ISBN: 9780849312625.

9. H. Baltes, O. Brand, G. K. Fedder, C. Hierold, J. G. Korvink, O. Tabata, Enabling Technology for MEMS and Nanodevices, Wiley-VCH, Weinheim, 2013, ISBN: 978-3-527-33498-8..

10. Danny Banks, Microengineering, MEMS, and Interfacing - A Practical Guide, Taylor & Francis, Boca Raton, 2006, ISBN: 978-0-8247-2305-7.

11. C.P. Wong, Kyoung-Sik (Jack) Moon, Yi Li, Nano-Bio- Electronic, Photonic and MEMS Packaging, Springer, New York, 2010, ISBN: 978-1-4419-0039-5.

12. Sandra Carrara, Nano-Bio-Sensing, Springer, New York, 2011, ISBN: 978-1-4419-6169-3.

Web links and Video Lectures (e-Resources):

- Introduction to MEMS & Microsystems: Prof. Santiram Kal, IIT Kharagpur: https://www.youtube.com/watch?v=j9y0gfN9WMg
- Application of MEMS, Prof. Santiram Kal, IIT Kharagpur: https://www.youtube.com/watch?v=JW7zZyFVpGM
- MEMS Fabrication Techniques: https://www.youtube.com/watch?v=f7KKd292WMQ
- Silicides and Copper Metallization: https://www.youtube.com/watch?v=eJF5Ot3HADU
- What is sensor: Its Types and Applications: https://www.youtube.com/watch?v=ht-_RmhLD7k

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Demonstrate the knowledge of the basics and develop applications for microsystems	Apply
CO2	Operate MEMS transducers	Apply
CO3	Implement applications of electrostatics in MEMS sensors and actuators	Apply

Program Outcome of this course

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

Mapping of COS and POs

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

SELF ASSEMBLY OF NANOSTRUCTURES			
Course Code	**22NST235**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

- To Extend their knowledge of design of innovative nanostructured materials based on basic chemistry, physics, biology and self assembly concepts applied to nanoelectronics, nanophotovoltaic and energy materials
- Self-assembly of nanomaterials and their nanohybrids for technological applications

Module-1	
Self organization of nanostructured materials, Growth Mechanism, Self assembly of Nanostructures: Chemical, physical and biological self assembly, Assembling and patterning of particles, Self organization of different Nano-morphologies (Quntum Dots, Nanorods, Nanowires and Nanotubes).	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation
Module-2	
Self Assembled Monolayers (SAM), Guided Self Assembly - Nanolithography - Surface Topography - Surface Wetting - Electrostatic force; Nanomanipulators - Grippers – design - gripper arm geometry.	
Teaching-Learning Process	. Chalk and talk method / PowerPoint Presentation
Module-3	
Bottom-up manufacturing: bottom-up approach, Self-assembly of single electron transistors, Photovoltaic related devices, Langmuir Bladgett films (LB): principle of formation of monolayer formation – from molecules to nanoparticles, compression of monolayer-fabrication of LB films- applications.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation
Module-4	
Self-Assembly by micro contact printing- creating the stamp, substrate- creating self assembled monolayers - applications, Macroscopic expressions of Natural Nanomaterials- Hierarchical Ordering in Natural Nanoscale Materials	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation
Module-5	
Bio-Inspired Approach for Complex Superstructures and Biological World, Self Assembly in biological systems: Superhydrophobicity, Self cleaning property, Multi scale ordering and function in Biological Nanoscale Materials: Proteins, Lipids, DNA and RNA and Shell as a Composite Materials.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Books

1. Self Organized Nanoscale Materials: Nanostructure Science and Technology by Motonari Adachi and David J. Lockwood, 2006 Springer Science, Business Media, Inc. NY, USA
2. Self-Assembled Nanostructures: Jin Z. Zhang, Zhong-lin Wang, Jun Liu, Shaowei Chen, and Gang-yu Liu, 2003 Kluwer Academic/Plenum Publishers, NY, USA
3. Nanoparticles: Theory to Applications by Günter Schmid, 2010 WILEY-VCH Verlag GmbH & Co. KGaA, Boschstr. 12, 69469 Weinheim.
4. Hand Book of Nanotechnology, by Bharat Bhushan, 2007, Springer Science+Business Media, Inc, NY, USA.
5. Prospects in Nanotechnology: Toward Molecular Manufacturing, Markus Krummenacker and James Lewis (Editors), Wiley 1995.

Web links and Video Lectures (e-Resources):

- Nano structured materials-synthesis, properties, self assembly and applications, Prof. A. K. Ganguli, IIT Delhi: https://www.youtube.com/watch?v=iZi-xIDBGH0
- Self Assembled Monolayers (SAM): https://www.youtube.com/watch?v=kPnweOCTnZI
- Langmuir Bladgett films (LB): https://www.youtube.com/watch?v=8zslCUnXrHg
- Microcotact printing: https://www.youtube.com/watch?v=uEKqOAIDei4
- Superhydrophobicity: https://www.youtube.com/watch?v=27bq3o3y8Os

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Demonstrate self-assembled nanostructures	Apply
CO2	Understand bottom-up manufacturing	Understand
CO3	Create bioinspired things for society	Apply

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5
6	The engineer and society	6
7	Environment and sustainability	7

Mapping of COS and POs

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

NANOELECTRONICS AND BIOELECTRONICS			
Course Code	**22NST241**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

1. To introduce the students to nanoelectronics, nanodevices and molecular electronics
2. To identify quantum mechanics behind nanoelectronics
3. To explore the application of biosensors and bioelectronics

Module-1

LEDs and Semiconductor Lasers

Fundamentals of Semiconductor physics, Review of quantum confinement theory, optical phenomena in various quantum structures: quantum wells, quantum wires, quantum dots, superlattices. GaAs/ GaAlAs quantum well lasers, quantum wire lasers, quantum dot lasers, white light LEDs, vertical cavity surface emitting lasers, quantum cascade lasers, quantum well infrared detectors, digital logic based on quantum wells, GaN and other visible LEDs, semiconductor lasers.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Nanoscale MOSFETs

Challenges in miniaturization, quantum effects, thin oxides, random dopant fluctuations, tunneling and subthreshold currents, power density, hot electron effects, fundamental limits of MOS operations, MODFET (Modulation Doped FET), GaN based HEMT (High Electron Mobility Field Effect Transistors). - Grippers – design - gripper arm geometry.

Teaching-Learning Process	. Chalk and talk method / PowerPoint Presentation

Module-3

Molecular Nanoelectronics

Molecular nanowires, organic LEDs, organic FETs, carbon nanotube and grapheme based FETs, Silicon nanowire based FETs,

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Single Electron Tunneling Phenomena and Devices

Single electron tunneling phenomena, Coulomb blockade, Coulomb staircase, Bloch oscillations, resonant tunneling diode and resonant tunneling transistor,

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5

Nanobioelectronics

DNA based biosensors, protein based biosensors, materials for biosensor applications, quantum dot based bioimaging, DNA based logic and computing elements,

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Books

1. Nanoscale Transistors- Device Physics, Modeling and Simulation, M. Lundstrom and J. Guo, Springer, 2005, ISBN- 978-0-387-28003-5, 978-0-387-28002-8, 978-1-4419-3915-9.
2. Nanoelectronics- principles and devices, M. Dragoman and D. Dragoman, Artech House publishers, 2005, ISBN: 9781596933682.
3. Fundamentals of modern VLSI devices, Y. Taur and T. H. Ning, Cambridge University Press, 1998, ISBN: 0521559596, 9780521559591.
4. Nanoelectronics and Nanosystems: From Transistors to Molecular and Quantum Devices, K. Goser, P. Glosekotter and J. Dienstuhl, Springer, 2005, ISBN 978-3-662-05421-5.
5. Handbook of Thin Film Materials, volume 5, edited by H.S Nalwa, American Scientific Publishers, 2002, ISBN: 9780125129084, 9780080533247.
6. Encyclopedia of nanoscience and nanotechnology, Edited by H.S. Nalwa, American Scientific Publishers, 2007, ISBN: 1-58883-001-2 , ISBN: 1-58883-159-0.
7. Overview of Nanoelectronic Devices, D. Goldhaber Gordon, Proceedings of IEEE, volume 85, 1997.
8. Nanoelectronics and Information Technology, W. Rainer, Wiley, 2003, ISBN: 978-3-527-40927-3
9. Nanosystems, K.E. Drexler, Wiley, 1992, ISBN:0-471-57518-6
10. Science of fullerenes and carbon nanotubes, M.S. Dresselhaus and G. Dresselhaus, Academic press, 1996, ISBN: 9780080540771

Web links and Video Lectures (e-Resources):

- Semiconductor Optoelectronics, Prof. M. R. Shenoy, IIT Delhi: https://www.youtube.com/watch?v=Dt5kbf8JbJ0
- Nanoelectronics: Devices and Materials, FD SOI MOSFET, Prof. Navakanta Bhat, IIT Bangalore: http://www.infocobuild.com/education/audio-video-courses/electronics/NanoelectronicsDevicesMaterials-IIT-Bangalore/lecture-21.html
- Optoelectronic Materials and Devices, Prof. Monica Katiyar & Prof. Deepak Gupta, IIT Kanpur: https://www.youtube.com/watch?v=MC1zGEmrELA
- Single Electron Transistors, Coulomb Blockade: Dr. Madhu T., IITM: https://www.youtube.com/watch?v=OYJuwrsJu8s

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Understand the basic of nanoelectronics and bioelectronics	Understand
CO2	Explain operation of various electronics and biomedical devices, like FET, LED, MOSFET, etc.	Analyze
CO3	Create various nanostructures for fabrications of nanoelectronic devices and biomedical devices	Create

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5
6	The engineer and society	6

Mapping of COS and POs

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

SURFACE ENGINEERING OF NANOMATERIALS			
Course Code	**22NST242**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

- This course provides an overview on the various aspects of surface interactions with liquid-solid-gas environment.
- It provides a selective understanding on the surface phenomenon involved in mechanical, electrical, optical, and biological world.
- This course provides another dimension in the surface understanding – for eg., to look into the mechanical aspects in the bio world

Module-1

Introduction to Surfaces

Surfaces and Interfaces – Importance of Surfaces in Nano Regime – Thermodynamics of surfaces – surface energy – notation of surface structures – surface reconstruction -Surface and interfacial tension and measurement– contact angle and wetting – surfactants, and interfacial forces – Review of Surface Characterization Techniques – optical, topographic, chemical and mechanical properties (XPS, PIXE, RBS, SIMS, LEED, RHEED)

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Processes at Solid Surfaces

Adsorption – Physisorption and Chemisorption – Adsorption isotherms (Langmuir and BET) – Reaction Mechanism (Langmuir-Hinshelwood and Eley-Rideal) – Sticking Probability –Types of Catalyst – Homo vs Hetero - Properties and preparation of Catalyst – TON, TOF, E factor - Surface and electronic properties of metal and metal oxide catalyst and its principle behind catalysis – Sabatier Principle – Bronstedt – Polanyi relation - Role of Surfaces, Interfaces, Morphology in Catalysis– Active sites incatalysis & determination – porous materials and supported catalyst – spillover and reverse spillover - Sensor

Teaching-Learning Process	. Chalk and talk method / PowerPoint Presentation

Module-3

Role of Surfaces in Bio-nano interactions

Adhesion and its importance – Adhesion vs cohesion – Work in adhesion and cohesion - Theories on adhesion (Bradley, Hertz, JKR) - Methods of adhesion measurement (Scotch Tape, Peel test, Scratch, Blister, Ultrasonic and acoustic microcavitation methods) – Adhesion measurement in cell (observational, probing and counting techniques) - Surface modification and adhesion - Adhesion of nanoparticles, cells and between nanoparticle & cells - Cancer cell surface interaction.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Tribological Aspects of Surfaces

Tribological aspects of adhesion, friction and wear – Friction and Friction Types – Theories of Macro (Amontons, Coulomb) and Nanoscale friction (Tomlinson, Frenkel- Kontorova, Bowden and Tabor models)– Difference between macro and micro/nano tribology- Wear – Wear Mechanisms and types – identification of different mechanisms – Wear theory (Archard, Rabinowictz, Bassani and D'Acunto Theory)– Characterization techniques for friction and wear – Tribometer, Friction Force Microscopy, Nanoindentation and Nanoscratching – Methods to reduce wear and Friction –Fracture –Lubrication –Surface Coatings

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5	
Surfaces in Multidisciplinary Applications Colloids– Optical and Electrical properties – Colloids in Drug Delivery – Electrical and Electronic properties of Surfaces –zeta potential - Corrosion – Coatings for corrosion protection –High temperature issues - New coating concepts in multilayer structures – thermal barrier coatings. Bioinspired materials – Tribology in Human Body, Artificial organs and Medical devices –Nanosurfaces in Energy, Environmental, Automobile and Industrial Applications	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Books

1. Gabor A. Somorjai, Yimin Li, Introduction to Surface Chemistry and Catalysis, Second Edition, John Wiley & Sons, New Jersey, 2010, ISBN: 978-0-470-50823-7.
2. HaraldIbach, Physics of Surfaces and Interfaces, Springer-Verlag, Berlin, 2006, ISBN: 978-3-540-34709-5.
3. Pankaj Vadgama, Surfaces and interfaces for biomaterials, First Edition, CRC Press, Boca Raton, 2005, ISBN: 0-8493-3446-6.
4. Peter J. Blau, Friction Scienceand Technology- From concepts to applications, Second Edition, CRC Press, Boca Raton, 2009, ISBN: 978-1-4200-5404-0.
5. I. Chorkendorff, J.W. Niemantsverdriet, Concepts of Modern Catalysis and Kinetics, First Edition, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2003, ISBN: 3-527-30574-2.
6. Didier Astruc, Nanopaticles and catalysis, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2008, ISBN: 978-3-527-31572-7.
7. N. Birks, G. H. Meier, F. S. Pettit, Introduction to the high temperature oxidation of metals, Second edition, Cambridge University Press, 2006, 978-0-521-48042-0.
8. Bharat Bhusan, Nanotribology and Nanomechanics, Springer, Berlin, 2005, ISBN: 978-3-540-24267-3.

Web links and Video Lectures (e-Resources):

- Surfaces and interfaces, importance: IIT Kanpur: https://www.youtube.com/watch?v=akEmtQTnyHo
- Surface characterization techniques, IIT Bombay: https://www.youtube.com/watch?v=7QhoFk1GczA
- Adsorption isotherms, IIT Kharagpur: https://www.youtube.com/watch?v=ueAUsgoUaxA
- Colloids and Surfaces, Prof. Basavaraj Madivala Gurappa, IIT Madras: https://nptel.ac.in/courses/105106204

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Illustrate functional coatings (such as hydrophilic/ hydrophobic) and the measurement of physical properties	Apply
CO2	Execute surface characterization tools and interpretation of the outcome	Apply

Program Outcome of this course

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

Mapping of COS and POs

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

ADVANCED AND SMART MATERIALS			
Course Code	**22NST243**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

- The course aims at providing overview of latest development in the Advanced and Smart materials.
- Introduce concepts and principle behind the materials property
- Analyze the potential different nanomaterials for their application

Module-1	
Photonic Materials: Need for New Photonic Materials, composite materials for nonlinear optics, nanostructured waveguides for nonlinear optics quantum and nonlinear optics for advanced imaging applications. Nanophotonics—An Exciting Frontier in Nanotechnology. Nanophotonics at a Glance.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation
Module-2	
Spintronic Materials: Modelling the growth of Mn on semiconductor substrates, Dilute magnetic semiconductor nanocrystals, Advances in wide bandgap materials for semiconductor spintronics	
Teaching-Learning Process	. Chalk and talk method / PowerPoint Presentation
Module-3	
Plasmonics: Metallic Nanoparticles and Nanorods, Metallic Nanoshells. Local Field Enhancement, Subwavelength Aperture Plasmonics, Plasmonic Wave Guiding. Applications of Metallic Nanostructures. Radiative Decay Engineering.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation
Module-4	
Smart Materials Thermoresponsive materials, piezoelectric materials, electrostrictive and magnetostrictive materials, Polychromic, Chromogenic or Halochromic Materials	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation
Module-5	
Magnetic materials, superparamagntism in metallic nanoparticles, Giant and colossal magnetic materials, ferrofluids, ER and MR fluids, biomimetic materials, smart gel, shape memory alloys and polymers	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

TEXT BOOKS:

1. Introduction to Solid State Physics, C. Kittel, Wiley Eastern
2. A practical approach to X-Ray diffraction analysis by C.Suryanarayana
3. Semiconductor Physics, P. S. Kireev, MIR Publishers.

References:

1. Solid State Physics, A. J. Dekkar, Prentice Hall Inc.
2. Introduction to Superconductivity, M. Tinkham, McGraw-Hill, International Editions
3. Elementary Solid State Physics: Principles and applications, M. A. Omar, Addison-Wesley.
4. Advanced Materials in Catalysis, Frank Bolz, Academic Press, 1977

Advanced Healthcare Materials Tiwari, A. (ed) (2014), John Wiley & Sons, Inc., Hoboken, NJ, USA.

Web links and Video Lectures (e-Resources):

- Integrated Photonics Devices and Circuits, IITM: https://www.youtube.com/watch?v=xasZDwgSFiE
- Spintronic Materials, Colossal Magentoresistive Oxides: https://www.youtube.com/watch?v=ABZz--4XkNs
- Plasmonic nanoparticles, IIT Bombay: https://www.youtube.com/watch?v=cWOFsv4a8sU
- Introduction to Smart Materials: https://www.youtube.com/watch?v=76QWN1tY8fo
- Magnetic materials, IIT Kanpur: https://www.youtube.com/watch?v=6QUFuZpCgGw

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Interpret smart materials for applications related with safe societal needs	Understand
CO2	Demonstrate advanced material's engineering applications in thermal, magnetic, spintronic, and electronics based devices	Apply

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5
6	Ethics	8
7	Life-long learning	12

Mapping of COS and POs

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

NANO AND BIOPHOTONICS			
Course Code	**22NST244**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

- To Understand the basics of Nanophotonics and Biophotonics based on Electromagnetic theory.
- Concepts of Photonics band gap will be understood.
- To Learn the techniques on fabrication of 1, 2 and 3 D photonics crystals.
- Learn the applications of Bioderived and Bioinspired materials for photonic applications.
- Concepts of quantum dots and their application in nanotechnology for bioimaging is studied.

Module-1

Introduction to photonics

Electromagnetic properties of nanostructures – Wavelength and Dispersion laws – Density of states – Maxwell and Helmholtz equations – Photonic band-structure and photonic band gap - Propagation of light in periodic media. Band structure in periodic media – 1D and 2D cases.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Photonic Crystals

Fabrication of photonic crystals: Photonic crystals by self-assembly - Photonic Crystals by Microfabrication - Photonic Crystals with Tunable Properties.

Harmonic generation in photonic nanostructures: Metal nanoparticles, Nanoparticles in monolayer – planar photonics structures - photonic crystals.

Teaching-Learning Process	. Chalk and talk method / PowerPoint Presentation

Module-3

Photobiology

Interaction of light with cells: Light absorption in cells – Light induced cellular processes photochemistry induced by exogenous photosensitizers – Interaction of light with tissues: Nature of Optical interactions – Measurement of optical properties of a tissue – Light-induced Processes in Tissues – Autofluorescence, photochemical processes, thermal effects, photoablation, plasma induced ablation and photodisruption

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Nanotechnology for biophotonics: The interface of bioscience, nanotechnology and photonics - Semiconductor quantum dots for bioimaging – Metallic nanoparticles and nanorods for Biosensing – Up-converting nanophores - Inorganic nanoparticles – Pebble nanosensors for Invitro Bioanalysis - Nanoclinics for optical diagnostics and Targeted therapy

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5

Biomaterials for Photonics: Photonics and Biomaterials – Bioderived materials (Baceriorhodopsin, Green Fluorescent Protein, DNA, Bio-objects and biocolloids) – Bioinspired materials – Biotemplates (DNA and Viruses as templates) – Bacteria as synthesizers for photonic polymers.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

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

Suggested Learning Resources:

1. Introduction to Nanophotonics, Sergey V. Gaponenko, Cambridge University Press, New York, ISBN-13 978-0-521-76375-2 (2010)

2. Photonic crystals: Physics and Technology, (Eds.) C. Sibilia, T. M. Benson, M. Marciniak, T. Szoplik, (ISBN: 978-88-470-0843-4) (2008)

3. Photonic Crystals (2nd edition), John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, Robert D. Meade, Princeton University Press, ISBN: 978-0-691-12456-8 (2008)

4. Introduction to Biophotonics, Paras N. Prasad, (John Wiley and Sons, New Jersey), ISBN: 0-471-28770-9 (2003)

5. Photonic Crystals:Towards Nanoscale Photonic Devices, J.-M. Lourtioz, H. Benisty, V. Berger, J.-M. Gerard, D. Maystre, A. Tchelnokov, ISBN-13 978-3-540-24431-8, Springer-Verlag Berlin Heidelberg (2005)

6. Principles of Nanophotonics, Motoichi Ohtsu, et al. ISBN : 13: 978- 1- 58488- 972- 4, by Taylor & Francis Group, LLC (2008)

7. Advances In Biophotonics, (Eds.) Brian C. WilsonValery V. Tuchin and Stoyan Tanev, IOS Press, ISBN 1-58603-540-1, (2005)

8. Biophotonics, Optical Science and Engineering for the 21st Century, (Ed.) Xun Shen and Roeland Van Wijk, ISBN-10: 0-387-24995-8; ISBN-13: 978-0387-24995-7; eISBN: 0- 387-24996-6

9. Nano Biophotonics: Science and Technology, (Eds) Hiroshi Masuhara, Satoshi Kawata and Fumio Tokunaga, ISBN-13: 978-0-444-52878-0; ISBN-10: 0-444- 52878-4, Elsevier (2007)

Web links and Video Lectures (e-Resources):

- Integrated Photonics Devices and Circuits, IITM: https://www.youtube.com/watch?v=xasZDwgSFiE
- Photonic Crystals and their Applications: https://www.youtube.com/watch?v=toa4XIa95Hs
- Biophotonics: https://www.youtube.com/watch?v=rS5AmU2bOdY
- Biomaterials: https://www.youtube.com/watch?v=yZKdFVAJcrE

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Articulate photonics at nano-scale	Understand
CO2	Produce photonic materials for advanced technologies such as optoelectronics, quantum computation, optical transmission etc.	Create

Program Outcome of this course

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

Mapping of COS and POs

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

INDUSTRIAL APPLICATIONS OF NANOTECHNOLOGY			
Course Code	**22NST245**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

1. To elucidate on advantages of nanotechnology based applications in each industry.
2. To provide instances of contemporary industrial applications of nanotechnology.
3. To provide an overview of future technological advancements and increasing role of nanotechnology in each industry

Module-1

Nanotechnology in Electrical and Electronics Industry

Advantages of nano electrical and electronic devices –Electronic circuit chips – Lasers - Micro and Nano-Electromechanical systems – Sensors, Actuators, Optical switches, Bio-MEMS –Diodes and Nano-wire Transistors - Data memory –Lighting and Displays – Filters (IR blocking) – Quantum optical devices – Batteries - Fuel cells and Photo-voltaic cells – Electric double layer capacitors – Lead-free solder – Nanoparticle coatings for electrical products

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Nanotechnology in Biomedical and Pharmaceutical Industry

Nanoparticles in bone substitutes and dentistry – Implants and Prosthesis - Reconstructive Intervention and Surgery – Nanorobotics in Surgery – Photodynamic Therapy - Nanosensors in Diagnosis– Neuro-electronic Interfaces – Protein Engineering – Drug delivery – Therapeutic applications.

Teaching-Learning Process	. Chalk and talk method / PowerPoint Presentation

Module-3

Nanotechnology in Chemical Industry

Nanocatalyts – Smart materials – Heterogenous nanostructures and composites – Nanostructures for Molecular recognition (Quantum dots, Nanorods, Nanotubes) – Molecular Encapsulation and its applications – Nanoporous zeolites – Self-assembled Nanoreactors - Organic electroluminescent displays

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Nanotechnology in Agriculture and Food Technology

Nanotechnology in Agriculture -Precision farming, Smart delivery system – Insecticides using nanotechnology – Potential of nano-fertilizers - Nanotechnology in Food industry - Packaging, Food processing - Food safety and bio-security – Contaminant detection – Smart packaging

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5	
Nanotechnology In Textiles And Cosmetics **Nanofibre production** - Electrospinning – Controlling morphologies of nanofibers – Tissue engineering application – **Polymer nanofibers** - Nylon-6 nanocomposites from polymerization - Nano-filled polypropylene fibers - **Bionics**– Swim-suits with shark-skin-effect,Soil repellence, Lotus effect - Nano finishing in textiles (UV resistant, antibacterial, hydrophilic, self-cleaning, flame retardant finishes) – **Modern textiles** (Lightweight bulletproof vests and shirts, Colour changing property, Waterproof and Germ proof, Cleaner kids clothes, Wired and Ready to Wear) **Cosmetics –** Formulation of Gels, Shampoos, Hair-conditioners (Micellar self-assembly and its manipulation) – Sun-screen dispersions for UV protection using Titanium oxide – Color cosmetics.	
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

1. Mark A. Ratner and Daniel Ratner,Nanotechnology: A Gentle Introduction to the Next Big Idea, Pearson (2003). 10 NT – 12–13 – SRM – E&T
2. Bharat Bhushan,Springer Handbook of Nanotechnology, Barnes & Noble (2004).
3. Neelina H. Malsch (Ed.),Biomedical Nanotechnology, CRC Press (2005)

References:

1. Udo H. Brinker, Jean-Luc Mieusset (Eds.), Molecular Encapsulation: Organic Reactions in Constrained Systems,Wiley Publishers (2010).
2. Jennifer Kuzma and Peter VerHage, Nanotechnology in agriculture and food production, Woodrow Wilson International Center, (2006).
3. Lynn J. Frewer, WillehmNorde, R. H. Fischer and W. H. Kampers, Nanotechnology in the Agri-food sector, Wiley-VCH Verlag, (2011).

4. P. J. Brown and K. Stevens, Nanofibers and Nanotechnology in Textiles, Woodhead Publishing Limited, Cambridge, (2007).
5. Y-W. Mai,Polymer Nano composites, Woodhead publishing, (2006).
6. W.N. Chang, Nanofibres fabrication, performance and applications, Nova Science Publishers Inc, (2009).

Web links and Video Lectures (e-Resources):

- Introduction to Nanoelectronics, IISc Bengaluru: https://www.youtube.com/watch?v=wdNFCWLuC10
- Biomedical nanotechnology, https://www.digimat.in/nptel/courses/video/102107058/L01.html
- Heterogeneous Nanocatalysis: IIT Gandhinagar: https://www.youtube.com/watch?v=bNtTfGPfy_Y
- Nanotechnology in Agriculture - Prof Mainak Das, IIT Kanpur: https://www.youtube.com/watch?v=hdDBvC7kop8
- Nanofibers: https://www.youtube.com/watch?v=i-EmUjv-fL4

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Demonstrate the knowledge of various industrial applications of nanotechnology.	Apply
CO2	Classify future technological advancements and increasing role of nanotechnology in each industry	Analyze

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5
6	The engineer and society	6
7	Environment and sustainability	7
8	Ethics	8
9	Life-long learning	12

Mapping of COS and POs

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

DEVICE FABRICATION AND CHARACTERISATION LAB			
Course Code	**22NSTL26**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)		SEE Marks	50
Credits	02	Exam Hours	03

Course objectives:

- The learning objectives of the course are Knowledge to design and develop the nanostructured based devices
- Hands on experience to fabricate the devices based on nanomaterials
- Knowledge of device operation, data measurement, analysis of the device performance and their application.

Sl.NO	Experiments
1	Gas/Pressure Sensors device fabrication and device parameter measurement and analysis
2	Dye sensitized solar cell device fabrication, I-V measurement and Efficiency calculation
3	To preparation of electrodes for supercapacitor and calculate its specific capacitance using Cyclic voltammetry.
4	To fabricate metal oxide thin/thick film and analyse surface features using AFM
5	Fabrication of thin/thick films and its Crystal structure analysis using XRD
6	Design and Synthesis of 1D inorganic nanostructures and analyse their size and morphology by scanning electron micrograph
7	Preparation of 2D nanostructures and measure their thickness and morphology by AFM.
8	Modification of electrodes by nanomaterial for voltammetric applications
	Demonstration Experiments (For CIE) if any
9	Fabrication of electrode for electrochemical oxidation of organic molecules.
10	Battery device Fabrication and its performance data analysis.

Course outcomes (Course Skill Set):

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

Design the nanomaterial for suitable application

Basic hands on experience to fabricate selected nanomaterials based devices

Knowledge to operate the device and measure data.

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation (CIE):

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

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

- Each experiment to be evaluated for conduction with observation sheet and record write-up. Rubrics for the evaluation of the journal/write-up for hardware/software experiments designed by the faculty who is handling the laboratory session and is made known to students at the beginning of the practical session.
- Record should contain all the specified experiments in the syllabus and each experiment write-up will be evaluated for 10 marks.
- Total marks scored by the students are scaled downed to 30 marks (60% of maximum marks).
- Weightage to be given for neatness and submission of record/write-up on time.
- Department shall conduct 02 tests for 100 marks, the first test shall be conducted after the 8th week of the semester and the second test shall be conducted after the 14th week of the semester.
- In each test, test write-up, conduction of experiment, acceptable result, and procedural knowledge will carry a weightage of 60% and the rest 40% for viva-voce.
- The suitable rubrics can be designed to evaluate each student's performance and learning ability.
- The average of 02 tests is scaled down to **20 marks** (40% of the maximum marks).

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

Semester End Evaluation (SEE):

SEE marks for the practical course is 50 Marks.

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

All laboratory experiments are to be included for practical examination.

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

Students can pick one question (experiment) from the questions lot prepared by the internal

/external examiners jointly.

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

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

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

The duration of SEE is 03 hours

Suggested Learning Resources:

TEXT BOOKS:

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

References:

4. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition Harold P. Klug, Leroy E. Alexander
5. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)- David B. Williams and C. Barry Carter
6. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton..

CARBON BASED NANOSTRUCTURES			
Course Code	**22NST31**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:2	SEE Marks	50
Total Hours of Pedagogy	50	Total Marks	100
Credits	4	Exam Hours	3

Course Learning Objectives:

1. Introduce type of carbon based nanostructures tubes
2. Learn about the synthesis methods and growth mechanisms.
3. Understand different properties and applications of carbon nanotubes in various fields.
4. Importance of functionalization of carbon nanostructures

Module-1

Carbon Nanotubes (CNT): History, types of CNTs, synthesis methods, CVD method, Laser ablation and electric arc processes, growth mechanisms, purification and characterization methods, mechanical reinforcements, solid disordered carbon nanostructures.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Graphene: Background, structure, exfoliation or synthesis methods- physical methods- micromechanical (scotch tape method), CVD, electric arc process. Chemical approaches-Hammers method, oxidation and reduction of graphite, solvothermal, supercritical fluid, solvent sonication method, chemically modified graphene, electrochemical synthesis and other methods.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-3

Fullerenes and derivatives: Fullerenes and types, diamond like carbon, nanodiamond, clusters, metal carbide derived carbon nanostructures, synthesis and applications.

Nanostructures: Graphite, Whiskers, Cones, and Polyhedral crystals, structure, properties and applications.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Functionalization of carbon nanostructures: (CNT, Graphene and fullerenes)- reactivity, covalent functionalization-oxidative purification, defect functionalization, transformation and modification of carboxylic functionalization like amidation, thiolation, halogenations, hydrogenation, addition of radicals, sidewall functionalization through electorphilic addition, nano covalent exohedralfunctionalization, endohedro functionalization.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5

Properties of Carbon nanostructure: Electronic, Vibrational, Mechanical Properties of CNTs, optical properties & Raman spectroscopy of CNTs.

Application of Carbon nanostructure in Lithium ion battery, fuel cells, hydrogen storage, sensor applications, applications to nanoelectronics, nanocomposites, nanowires in drug delivery, polymer reinforcement and as filler materials.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks**

to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Books

TEXT BOOKS:

1. Carbon Nanotubes: properties and applications-Mchael J. O'Connell, Taylor & Francis, 2006
2. Nanotubes and Nanowires-CNR Rao and A Govindaraj RSC publishing
3. Handbook of Carbon, YuryGagotsi, Taylor & Francis, 2006

Reference

1. Physical properties of carbon nanotube- R. Satio
2. Applied physics of Carbon nanotubes: fundamentals of theory, optics and transport devices-S.Subramoney and S.V.Rotkins
   Carbon nanotechnology-Liming Dai

Web links and Video Lectures (e-Resources):

- Fullerenes and Carbon nanotubes: https://www.youtube.com/watch?v=9EKqNBvz4cA
- Carbon Materials and Manufacturing https://www.youtube.com/watch?v=AzyYyjPEqOk&t=1s
- Carbon Nanostructures https://www.youtube.com/watch?app=desktop&v=kCTED1wlQBU

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Identify the type of carbon nanotubes and different synthesis methods and growth mechanisms	Understand
CO2	Elucidate different properties and applications of carbon nanotubes in various fields and Understand the importance offunctionalization of carbon nanostructures their application of carbon nanostructure for different day-to-day applications	Apply

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

Program Outcome of this course

Mapping of COS and POs

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

COMPUTATIONAL METHODS FOR MODELLING AND SIMULATION			
Course Code	22NST321	CIE Marks	50
Teaching Hours/Week(L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning Objectives:

- Develop an understanding of scientific problems that are presented in mathematical forms such as differential equations and integral equations.
- Learn about Numerical methods to solve scientific problems and get introduced to their applications.
- Gain knowledge about simulating nanomaterials systems with the help of computation and simulation in a way that can be understood by all branches including biology.
- Develop good mathematical and computational skills that enable you to make computations for creating crystals and carbon nanotubes.
- Acquire competence in advanced computational techniques such as Monte Carlo simulations using Random numbers and finite difference and finite element methods.

Module 1: Introduction to Mathematical Modeling and Differential Equations	
Introduction to mathematical modeling and differential equations, First-order differential equations, Second-order differential equations, Higher-order differential equations Systems of differential equations, Numerical methods for solving differential equations Finite difference methods, Finite element methods	
Teaching – Learning Process	Chalk and talk method/Power Point Presentation
Module 2: Introduction to Numerical Methods	
Introduction to numerical methods, Root finding and optimization, Interpolation and curve fitting, Numerical differentiation and integration, Solving nonlinear equations, Solving systems of linear equations, Monte Carlo simulations using random numbers, Error analysis and convergence testing	
Teaching – Learning Process	Chalk and talk method/Power Point Presentation
Module 3: Simulation of Nanomaterial Systems	
Introduction to simulation of nanomaterial systems, Molecular dynamics simulation, Monte Carlo simulation, Quantum mechanics simulation, Classical simulations of materials Simulation of nanoparticles, Simulation of nanotubes, Simulation of nanocomposites	
Teaching – Learning Process	Chalk and talk method/Power Point Presentation
Module 4: Simulation for All Branches Including Biology (8 hours)	
Introduction to simulations for all branches including biology., Simulation of biomolecules, Simulation of proteins and nucleic acids, Simulation of biological membranes, Coarse-grained simulations, Multi-scale simulations, Simulation of drug delivery systems, Simulation of gene editing and CRISPR-Cas9 technology	
Teaching – Learning Process	Chalk and talk method/Power Point Presentation
Module 5: Advanced Computational Techniques (8 hours)	
Introduction to advanced computational techniques, Fourier analysis and fast Fourier transform. Wavelet analysis, Solution of partial differential equations, Spectral methods, Mesh-free methods, Boundary element methods, Immersed boundary methods	
Teaching - Learning Process	Chalk and talk method/Power Point Presentation

Assessment Details (both CIE and SEE)

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Continuous Internal Evaluation:

1. Three Unit Tests each of 20Marks
2. Two assignments each of 20 Marks or one Skill Development Activity of 40 marks to attain the COs and POs

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

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Books:

1. Introduction to Mathematical Modeling and Differential Equations by Igor B. Krasnov, Academic Press, ISBN: 978-0128048068, 2016. DOI: https://doi.org/10.1016/C2014-0-01381-6
2. First Course in Ordinary Differential Equations by Martin Braun, Springer, ISBN: 978-0387978949, 1993. DOI: https://doi.org/10.1007/978-1-4612-4350-2
3. Differential Equations with Applications and Historical Notes by George F. Simmons, McGraw Hill Education, ISBN: 978-0070575401, 1991. DOI: https://doi.org/10.2307/2316305
4. Introduction to Numerical Methods and MATLAB Programming for Engineers by Todd Young and Martin J. Mohlenkamp, Academic Press, ISBN: 978-0128046293, 2016. DOI: https://doi.org/10.1016/C2014-0-01447-4
5. Numerical Methods for Scientists and Engineers by Richard W. Hamming, Dover Publications, ISBN: 978-0486652412, 1987. DOI: https://doi.org/10.1002/zamm.19720520916
6. Numerical Recipes in C: The Art of Scientific Computing by William H. Press, Saul A. Teukolsky, William T. Vetterling, and Brian P. Flannery, Cambridge University Press, ISBN: 978-0521431088, 1992. DOI: https://doi.org/10.1017/cbo9781107415324
7. Monte Carlo Simulation and Finance by Don L. McLeish, CRC Press, ISBN: 978-1584886265, 2005. DOI: https://doi.org/10.1201/9781420028538
8. An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements by John R. Taylor, University Science Books, ISBN: 978-0935702750, 1997. DOI: https://doi.org/10.1119/1.18702
9. Introduction to Computational Materials Science: Fundamentals to Applications by Richard LeSar, Cambridge University Press, ISBN: 978-0521845871, 2013. DOI: https://doi.org/10.1017/cbo9781139029831
10. Molecular Dynamics Simulation: Elementary Methods by J. M. Haile, Wiley, ISBN: 978-0471819660, 1992. DOI: https://doi.org/10.1002/aic.690380630
11. Monte Carlo Simulation in Statistical Physics: An Introduction by Kurt Binder and Dieter W. Heermann, Springer, ISBN: 978-3540581540, 1997. DOI: https://doi.org/10.1007/978-3-662-03302-8
12. Computational Materials Science: From Basic Principles to Material Properties by Kaoru Ohno and Ryoichi Kawai, Springer, ISBN: 978-4431565147, 2018. DOI: https://doi.org/10.1007/978-4-431-55916-1
13. Simulation of biomolecules: "Introduction to Computational Biology: Maps, Sequences, and Genomes" by Michael S. Waterman, Chapman and Hall/CRC Press, 2004, ISBN 978-1-58488-417-9. DOI: https://doi.org/10.1201/9781420035803
14. Simulation of proteins and nucleic acids: "Molecular Modeling and Simulation: An Interdisciplinary Guide" by Tamar Schlick, Springer, 2010, ISBN 978-1-4419-1599-1. DOI: https://doi.org/10.1007/978-1-4419-1600-4
15. Simulation of biological membranes: "Molecular Dynamics Simulation: Elementary Methods" by J. M. Haile, Wiley-VCH, 1992, ISBN 978-0-471-55762-1. DOI: https://doi.org/10.1002/9780470141168
16. Fourier analysis and fast Fourier transform: "Numerical Recipes 3rd Edition: The Art of Scientific Computing" by William H. Press, Saul A. Teukolsky, William T. Vetterling, and Brian P. Flannery, Cambridge University Press, 2007, ISBN 978-0-521-88068-8. DOI: https://doi.org/10.1017/cbo9780511807447

Web links and Video lectures (e-Resources)

1. Differential Equations, https://www.khanacademy.org/math/differential-equations
2. Numerical Methods and Computation, https://ocw.mit.edu/courses/mathematics/18-330-numerical-methods-for-partial-differential-equations-spring-2012/video-lectures/
3. Nanomaterials and Nanotechnology, https://nptel.ac.in/courses/113/106/113106123/
4. Molecular Dynamics Simulation for Beginners, https://www.youtube.com/watch?v=cG5K5yD9RDI
5. Advanced Numerical Techniques, Coursera, https://www.coursera.org/learn/advanced-numerical-techniques

Skill Development Activities Suggested
- Assignments
- Quizzes
- Seminars

Course outcome (Course Skill Set)
At the end of the course:

CO	Description	Blooms Level
CO1	Apply mathematical modeling techniques to represent scientific problems as differential or integral equations.	RBTL: Apply
CO2	Analyze and solve differential equations using numerical methods such as finite difference and finite element methods.	RBTL: Analyze
CO3	Evaluate the suitability of different simulation methods for nanomaterial systems and apply them to simulate nanoparticles, nanotubes, and nanocomposites.	RBTL: Analyze
CO4	Demonstrate advanced computational techniques such as Fourier and wavelet analysis to solve partial differential equations and use error analysis and convergence testing to validate results.	RBTL: Apply

Program Outcome of this Course

Sl. No.	Description	Pos
1.	Engineering knowledge	1
2.	Problem analysis	2
3.	Design/development of solutions	3
4.	Conducting investigations of complex problems	4
5.	Modern tool usage	5
6.	Individual and Teamwork	9
7.	Communication Skills	10

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	X	X							X	X		
CO2	X	X		X					X	X		
CO3	X	X	X	X	X				X	X		
CO4	X	X		X					X	X		

NANO MATERIALS AND TECHNOLOGY IN BIOMEDICAL APPLICATIONS			
Course Code	**22NST322**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

- This course provides an overview on the various aspects of surface interactions with liquid-solid-gas environment.
- It provides a selective understanding on the surface phenomenon involved in mechanical, electrical, optical, and biological world.
- This course provides another dimension in the surface understanding – for eg., to look into the mechanical aspects in the bio world

Module-1

Bio ceramics for implant coating: calcium phosphates - hydroxy epilates Ti6Al4V and other biomedical alloys - implant tissue interfacing – metal organic CVD – use of tricalcium phosphate – biomimetic and solution based processing – osteo porosis – osteo plastic – regeneration of bones by using bio compactable ceramics – biointeractive hydro gels – PEG coating and surface modifications – PEG hyrogels patterned on surfaces – PEG based hyrogels

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Tissue Engineering : scaffolds for tissue fabrications – materials for scaffolds – materials for hydrogel scaffolds – scaffolds fabrications technologies – textile technologies – particulate –leaching techniques – phase separation – design of three-dimensional pore architecture – nano-featured and bioactive scaffolds – nano-fiber scaffolds – nanocomposite scaffolds – bioactive scaffolds – scaffolds for stem cells – micro and nanopatterned scaffolds - scaffolds and stem cells – Engineering biomaterial to control cell function – building structure into engineered tissues – fibrous proteins and tissue engineering .

Teaching-Learning Process	. Chalk and talk method / PowerPoint Presentation

Module-3

Nanomedicine: Diagnosis of diseases, treating and preventing of diseases – targeted for drug delivery – ligand coupled nanoparticle features – methods for coupling targeting ligands to nanoparticles – targeting modalities – barriers to tumor targeting *in vivo* – MRI contrast enhancement - future line of action – Gene delivery – Bio molecular motors - Nanoscale transport systems: molecular shuttle powered by Biomolecular motors

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Nanopharmacy: multi-targeted drugs – delivery of nucleic acids- barriers to therapeutic applications – interaction of organic molecules of the drug with pathological tissue – ligand targeted nanoparticles drug delivery: combining multiple functions - formation of nucleic acid core particle – protective steric coating – surface exposed ligands targeting specific tissues –biocompatible core-shell nanoparticles for medicine – configuration of core – shell structure with different cores, shells and biomolecules-least toxicity-nanocapsules-methods of changing surface characteristics- future prospects.

Module-5

Medical Devices: Imaging, implantable sensors, cell specific gene therapy, DNA chips and micro arrays, Surface immobilized protein nano structures Forensic Applications: Collection and analysis of evidence of different types of crime scenes including drugs, DNA analysis, blood splattering, serology, toxicology DNA nanotechnology DNA origami Application of DNA nanotechnology Drawbacks of DNA origami. Protein nanotechnology & applications. Glyco nanotechnology & applications. DNA nanomachines Protein nanomachines Demonstration of motility of bacteria Nanomachine communication

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

a. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reducedto 50.
b. The question paper will have ten full questions carrying equal marks.

Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

TEXT BOOKS:

1. Nanotechnology in Drug Delivery: Melgardt M. de Villiers, PornanongAramwit, glen s. Kwon, Springer, 2009
2. NanoBiotechnology: BionInspired Devices and Materials for the Future: OdedShoweyov, Ilan

Levy, Humana Press, New Jersey 2010
3. Nanobiotechnology, Concepts applications and Perspectives: C. M. Niemeyer and Chad A. Mirkin, Wiley VCH, 2009
4. DNA Arrays: Technologies and experimental strategies ed. E.V. Grigorenko, CRC Press 2002.
5. Robert.W.Kelsall, Ian.W.Hamley, Mark Geoghegan, Nano Scale Science And Technology, John Wiley and son, ltd., 2005

Reference books:

1. Robert.W.Kelsall, Ian.W.Hamley, Mark Geoghegan (Ed), Nano Scale Science And Technology, John Wiley and son, ltd., 2005
2. H.Fujita (Ed), Micromachines As Tools For Nanotechnology, Springer, 2003
3. Mick Wilson Kamali Kannangara Geooff Smith Michelle, Simmons Urkhard Raguse, Nano Technology, Overseas India private Ltd., 2005.
4. Gunter Schmid , Nano Particles, Jhon wiley and sons limited, 2004
5. K.K.Jain, Nano Biotechnology, Horizions Biosciences, 2006

Web links and Video Lectures (e-Resources):

1. Biomedical Nanotechnology: https://nptel.ac.in/courses/102107058

2.

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Demonstrate the knowledge on state-of-the-art and future nanotechnologies used for medical and biological science applications	Apply
CO2	Evaluate the suitable nanostructure for drug delivery systems application.	Apply

Program Outcome of this course

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

Mapping of COS and POs

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

NANO MATERIALS AND TECHNOLOGY IN FOOD AND AGRICULTURE			
Course Code	**22NST323**	CIE Marks	50
Teaching Hours/Week(L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives:

1. To provide students the opportunity to learn the most recent advances in agriculture nanotechnology
2. To train the students in application aspects of nanotechnology in food and agriculture fields
3. Explore the role of Nanotechnology in Food Processing.

Module-1

Agricultural Nanotechnology:

Conventional Farming: Issues and Limitations, Intensive Conventional Farming Affects Environment, Current Agricultural Production Systems, Nanotools -Nano processes, and Nanomaterials Production of Bionanomaterials from Agricultural Wastes**:** Cellulose and Nanocellulose from Citrus and Orange Wastes, Synthesis of Graphene Oxide from Agro wastes, Production of Amorphous Silica Nanoparticles from Agrowastes, Carbon Nanomaterials from Agrowastes,

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Module-2

Nanoengineering Superabsorbent Materials in Agriculture:

Introduction, Formation and Structure of Cross-Linked Polyacrylates, Formation and Structure of Cross-Linked Polyacrylates; Statistical Models, Mechanisms of Swelling in Superabsorbent Polymers, Mechanisms of Swelling in Superabsorbent Polymers; Hydration, Hydrogen Bonds, Properties of Superabsorbent Polymers, Absorption of Aqueous Solution, Moisture Absorption Superabsorbent Polymers Application in Agriculture Superabsorbent/Clay Nanocomposites

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Module-3

Nanotechnology in plant protection:

Nanotechnology and Their Applications in Insect's Pest Control; Formulations of Nanoinsecticides-Nanoemulsions, Components, Preparation, Types and Methods, Nanoparticle-Based Plant Disease Management; Interactions between NPs, Pathogens, and Plants, Plant Disease Diagnosis Using different NPs, Nanotechnology in Microbial Plant Pathogen and insect Management, Targeted Delivery of Agrochemicals Using Nanotechnology, Nanobased Pesticides in Agriculture, Nano-based Fertilizer Efficiency, Improving Plant Traits against Environmental Stresses Using Nanotechnology, Nanotechnology and Its Applications in Water Conservation

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Module-4

Nanoparticles in food production and diagnostics:

Food and New Ways of Food Production - Efficient Fractionation of Crops Efficient Product Structuring -Optimizing Nutritional Values - Applications of Nanotechnology in Foods: Sensing, Packaging, Encapsulation, Engineering Food Ingredients to Improve Bioavailability - Nanocrystalline Food Ingredients - Nanoemulsions - Nano-Engineered Protein Fibrils as Ingredient Building Blocks Preparation of Food Matrices - Concerns about Using Nanotechnology in food production. Diagnostics Enzyme Biosensors and Diagnostics - DNA- Based Biosensors and Diagnostics Radiofrequency Identification- Integrated Nanosensor Networks: Detection and Response- Lateral Flow (Immuno) assay - Nucleic Acid Lateral Flow (Immuno)assay - Flow-Through (Immuno)assays - Antibody Microarrays Surface Plasmon Resonance Spectroscopy.

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Module-5

Nanotechnology in food packaging:

Crop improvement - Reasons to Package Food Products - Physical Properties of Packaging Materials - Strength - Barrier Properties Light Absorption – Structuring of Interior Surfaces - Antimicrobial Functionality - Visual Indicators – Quality Assessment - Food Safety Indication - Product Properties - Information and Communication Technology - Sensors -Radiofrequency Identification Technology- Risks - Consumer and Societal Acceptance.

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Assessment Details(both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Test each of **20Marks**
2. Two assignments each of **20Marks**or **one Skill Development Activity of 40 marks**

To attain the Cos and POs

The sum of three tests, two assignments/skill Development Activities, will be**scaleddownto50marks**

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

Semester End Examination:

1 The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.

2 The question paper will have ten full questions carrying equal marks.

3 Eachfullquestionisfor20marks.Therewillbetwofullquestions(withamaximumoffoursub-questions) from each module.

Suggested Learning Resources:

Reference Books:

1) Nanobiotechnology Applications in Plant Protection by Kamel A. Abd-Elsalam and Ram Prasad, Volume 2, Springer, 2018.
2) Nanotechnology an Agricultural Paradigm by Ram Prasad, Manoj Kumar, Vivek Kumar Springer, 2017.
3) Nanoscience in Food and Agriculture by Shivendu Ranjan, Volume 1, Springer, 2016.
4) Nanotechnology and Plant Sciences by Manzer H. Siddiqui, Springer, 2015.
5) Nanoparticle Assemblies and Superstructures by Nicholas A. Kotov, CRC, 2006.
6) Nanotechnology in agriculture and food production by Jennifer Kuzma and Peter VerHage, Woodrow Wilson International, 2006.
7) Bionanotechnology by David S Goodsell, John Wiley & Sons, 2004.
8) Nanobiomaterials Handbook by Balaji Sitharaman, Taylor & Francis Group, 2011.

Weblinks and Video Lectures (e-Resources):

1) **NPTEL Course on Nanotechnology in agriculture** https://youtu.be/hdDBvC7kop8

2) NPTEL Course on Nanotechnology in Food processing
https://www.youtube.com/watch?v=DOAo7LtwXlQ

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	BloomsLevel
CO1	Explain concepts of nanotechnology in food packaging and processing	Comprehension and evaluation
CO2	Demonstrate the applications of nanotechnology in agriculture industry.	Apply

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5
6	The engineer and society	6
7	Environment and sustainability	7
8	Ethics:	8
9	Individual and teamwork:	9
10	Communication	10
11	Lifelong learning	12

Program Outcome of this course

Mapping of COS and POs

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

NANOMATERIALS AND TECHNOLOGY IN CIVIL ENGINEERING APPLICATIONS			
Course Code	**22NST324**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning Objectives: This course is designed to give an overview on

1. The role of Nanomaterials in civil and construction engineering
2. Nanomaterials application in strength, stability and resistance to chemical, Biological and Mechanical attack
3. Nanomaterials for smart buildings and quality construction

Module-1

Nanomaterials as Construction Materials : History of Cementitious Systems, Current Trends in Nano-modification of Cementitious Systems, **Nano-seeding and Crystallization Control:** The Hardening of Construction Materials: Hydration in Ordinary Portland Cement, Correlation between Hydrates, Microstructure and Cohesion Properties in Cement, Gypsum Hydration, Hydration of Plaster. Experimental Techniques to Characterize the Microstructure Development. Nano-engineering of Nucleation: Design of C-S-H Nucleation and Growth. Nano-modification of Crystal Growth: Nano-modification of Gypsum Growth, From Hydration to Crystallization, From Microscopic to Macroscopic

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Nanomaterials in Cement- The Effect of Nanomaterials on Cement Hydration and Reinforcement: Effects of Nanomaterials and SWCNT on the Hydration of Sonicated OPC, Dispersion of SWCNT for Use in Cementitious Composites, Effects of SWCNT and Other Nanomaterials on the Hydration of C3S and OPC, Reinforcing Behavior in SWCNT Composites

Teaching-Learning Process	. Chalk and talk method / PowerPoint Presentation

Module-3

Multifunctional and Smart Carbon Nanotube Reinforced Cement-Based Materials: Current Approaches for Dispersing CNTs in Cement-Based Materials, Reinforcement Mechanisms, Mechanical Properties of CNTs, Mechanical Properties of Nanocomposites, Electrical, Piezoresistive Thermal Conductive and Damping Properties of CNTs Reinforced Cement-Based Materials, Potential Structural Applications of CNTs Reinforced Cement-Based Materials, Challenges for Development and Deployment of Multifunctional and Smart CNTs Reinforced Cement-Based Materials

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Nanomaterials-Enabled Multifunctional Concrete and Structures: Self-sensing Nano-concrete and Structure, Piezoresistivity of Nano-concrete and the Modeling, Effect of Water Content on Electrical Property of CBCC and the Water-Proofing Method, Self-sensing Concrete Structures, Mechanical Properties of Nano-concrete, Microstructure, Strength, Abrasion Resistance of Concrete Containing Nano-particles, Flexural Fatigue Performance of Concrete Containing Nano-particles for Pavement, Future of Multifunctional Nano-concrete

Module-5

Next-Generation Nano-based Concrete Construction Products: A Review: Incorporation of Nanoscale and Nanostructured Materials: Incorporation of Nano-SiO2, during Mixing, Incorporation of Nano-TiO2, Incorporation of Nano-Al_2O_3, Incorporation of Nano-ZrO2, Calcium Carbonate Nano Particle Addition, Early Age Strength Increase of Belite Cement, Reinforcements of Nanotubes/Nanofibers, Nano Clay Composite. Self-healing Polymer to Control Microcracking, Self-

sensing of Concrete Stress, Self Consolidating Concrete (SCC), Reactive Powder Concrete (RPC), Nano porous Thin Film Technology to Improve Concrete Performance, Nano-engineering of Concrete Pore Solution, Controlled Release of Admixtures, Nanotechnology in Building, Nanotechnology Based Devices

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks** to attain the COs and POs

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

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

Semester End Examination:

a. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reducedto 50.
b. The question paper will have ten full questions carrying equal marks.

Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Textbook

1. D. Linden, Handbook of Batteries and Fuel Cells, Mcgraw-Hill, Noew York,1984
2. W. A. van Schalkwijk and B. Scrosati, Advances in Lithium- Ion Batteries, Kluwer Academic Publishers, Newyork, 2002
3. Linden , D. and Reddy , T.B. (2002) Handbook of Batteries , 3rd edn , McGraw - Hill , New York.

Reference

4. Crompton, T.R. (2000) Battery Reference Book , 3rd edn , Newnes , Oxford .
5. K. E. Aifantis and S. A. Hackney and R. Vasant Kumar, High Energy Density Lithium Batteries, Wiley-VCH Verlag, 2009.
6. University of Cambridge (2005) DoITPoMS Teaching and Learning Packages, http://www.doitpoms.ac.uk/tlplib/batteries/index.php (accessed 5 February 2010).
6. K. K. Jain, Nano Biotechnology, Horizions Biosciences, 2006

Web links and Video Lectures (e-Resources):

1. **Nano Materials and technology in construction: https://www.youtube.com/watch?v=NYhBRrC10xo**
2. **Nanotechnology and sustainability in concrete construction: https://youtu.be/NLonPfEDCGk**
3. **Nano engineered Concrete: https://youtu.be/ewR3Bslgyx4**

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)

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

Sl. No.	Description	Blooms Level
CO1	Identify suitable Nanomaterials for civil and construction engineering.	Apply
CO2	Demonstrate the knowledge of nanotechnology in smart and sustainable buildings.	Apply

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5
6	The engineer and society	6
7	Environment and sustainability	7
8	Ethics	8
9	Individual and teamwork	9
10	Communication	10
11	Lifelong learning	12

Mapping of COS and POs

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

NANOMATERIALS IN ENERGY GENERATION AND STORAGE SYSTEMS			
Course Code	**22NST325**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning Objectives:

1. Learn about basic principles of different renewable energy technology.
2. Apply nanomaterial in improving renewable energy storage and generation application.
3. Understand the nanosize and morphology influence on improving energy generation and storage efficiency.

Module-1

Renewable energy Technology: Energy challenges, nanomaterials and nanostructures in energy harvesting, developments and implementation of nanotechnology based renewable energy technologies, solar cell structures: quantum well and quantum dot solar cells, photo-thermal cells for solar energy harvesting, thin film solar cells, CIGS solar cells, Dye sensitized solar cells. Organic PV cells, Concentrated solar power (CSP): Reflective materials, absorptive coatings, thermal storage.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Energy storage: Introduction, Battery types, Li-ion Battery, Battery components materials, cathodes, anodes, effect of nanosize on energy storage and electrode materials performance. Next generation batteries, Li-Air, Li-S, Na ion battery, Mg ion battery. LIB for automobiles application, EV's, HEV, PHEV and power grid.

Teaching-Learning Process	. Chalk and talk method / PowerPoint Presentation

Module-3

Super capacitors: Introduction, Electrochemical energy storage, Electrochemical capacitors, Electrochemical double layer capacitor, electrode materials supercapacitors, Hybrid Nanostructures for supercapacitors- metal oxides, conducting polymers, Electrolytes for super capacitors, types of electrolytes.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Hydrogen Generation and storage technology: Hydrogen production methods, Concept of Grey, Blue and Green Hydrogen production, Electrochemical and photocatalytic H_2 Generation using Nanomaterials, purification, hydrogen storage methods and materials: metal hydrides and metal organic framework materials, volumetric and gravimetric storage capacities, hydriding and dehydriding kinetics, high enthalphy formations and thermal management during hydriding reaction, multiple catalytic- degradation of sorption properties, automotive applications. Catalyst of hydrogen production, steam reforming & Water splitting. Nanoporous membranes for hydrogen separation.

Teaching-Learning Process: Chalk and talk method / PowerPoint Presentation

Module-5

Fuel cell technology: Fuel cell principles, types of fuel cells (Alkaline Electrolytie, phosphoric acid, Molten carbonate, solid oxide and direct methanol and proton exchange fuel cells), Principle and operation of proton exchange membrane (PEM) fuel cell, materials and fabrication methods for fuel cell technology, micro fuel cell power sources-biofuels.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

1. Three Unit Tests each of **20 Marks**
2. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks**

to attain the COs and POs

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

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

Semester End Examination:

a. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reducedto 50.
b. The question paper will have ten full questions carrying equal marks.

Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Text Book

1. D. Linden, Handbook of Batteries and Fuel Cells, Mcgraw-Hill, Noew York,1984
2. W. A. van Schalkwijk and B. Scrosati, Advances in Lithium- Ion Batteries, Kluwer Academic Publishers, Newyork, 2002
3. Linden , D. and Reddy , T.B. (2002) Handbook of Batteries , 3rd edn , McGraw - Hill , New York.

Reference

4. Crompton, T.R. (2000) Battery Reference Book , 3rd edn , Newnes , Oxford .
5. K. E. Aifantis and S. A. Hackney and R. Vasant Kumar, High Energy Density Lithium Batteries, Wiley-VCH Verlag, 2009.
6. University of Cambridge (2005) DoITPoMS Teaching and Learning Packages,http://www.doitpoms.ac.uk/tlplib/batteries/index.php (accessed 5 February 2010).
7. K.K.Jain, Nano Biotechnology, Horizions Biosciences, 2006

Web links and Video Lectures (e-Resources):

1. **Nano Materials for Energy Conversion and Storage : https://youtu.be/YVNplIT-Diw**
2. **Hydrogen Production: https://youtu.be/JGe8R0N20ps**
3. **Hydrogen Energy: Production, Storage, Transportation and Safety: https://youtu.be/anDF-nUHZW4?list=PLOzRYVm0a65dtZiqOUeyWCiCWL4vWaDwj**
4. **Super Capacitors: https://youtu.be/DJ0Agkp8WlQ**

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome (Course Skill Set)
At the end of the course the student will be able to :

Sl. No.	Description	Blooms Level
CO1	Demonstrate the knowledge on concepts of advances in Renewable energy technologies	Apply
CO2	Evaluate the suitable nanostructure for improving energy storage and generation efficiency of the systems. .	Apply

Program Outcome of this course

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5
6	Individual and team work	9
7	Communication	10
8	Life long learning	12

Mapping of COS and POs

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

NANOTECHNOLOGY AND ENVIRONMENT			
Course Code	22NST331	CIE Marks	50
Teaching Hours/Week(L:P:SDA)	2:0:2	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning Objectives:

1. To provide students with a thorough understanding of the principles and applications of nanotechnology in environmental science and engineering.
2. To enable students to design and analyze nanotechnology-based solutions for environmental challenges, including water and air pollution control and sustainable energy systems.
3. To prepare students for careers in research, industry, or academia that involve the application of nanotechnology in environmental science and engineering.
4. To equip students with the critical thinking and communication skills necessary to evaluate the environmental impact of nanotechnology-based solutions.

Module 1: Introduction to Nanotechnology and Environment

Introduction to nanotechnology and its applications in environmental science and engineering, Properties of nanoparticles and their relevance to environmental applications, Current status and future prospects of nanotechnology in environmental science and engineering, Safety and ethical issues associated with the use of nanotechnology in the environment, Role of nanotechnology in addressing environmental challenges, including pollution, climate change, and energy security; Nanotechnology-based solutions for water and air pollution control, sustainable energy production, and waste management, Regulatory aspects of nanotechnology in the environment, Emerging trends and challenges in nanotechnology and environment.

Teaching – Learning Process	Chalk and talk method/Power Point Presentation

Module 2: Nanoparticles and Environmental Fate

Fate and transport of nanoparticles in the environment; Behavior of nanoparticles in different environmental matrices (air, water, soil, and sediments); Factors affecting the fate and transport of nanoparticles, including particle size, surface charge, and coating; Environmental risks associated with the use of nanoparticles; Methods for measuring and monitoring nanoparticles in the environment; Environmental risk assessment and management of nanoparticles; Life cycle assessment of nanoparticles in environmental applications; Case studies of nanoparticle impact on the environment and human health.

Teaching – Learning Process	Chalk and talk method/Power Point Presentation

Module 3: Nanotechnology for Water Treatment

Overview of water treatment technologies; Role of nanotechnology in water treatment and purification; Nanoparticle-based adsorption and membrane filtration processes; Nanoparticle-based sensors for water quality monitoring; Nanotechnology-based approaches for desalination and water reuse; Nanoparticle-based disinfection and sterilization of water; Treatment of emerging contaminants using nanotechnology; Economic and environmental aspects of nanotechnology-based water treatment systems.

Teaching – Learning Process	Chalk and talk method/Power Point Presentation

Module 4: Nanotechnology for Air Pollution Control

Overview of air pollution and its sources; Role of nanotechnology in air pollution control and remediation; Nanoparticle-based catalysts for the removal of air pollutants; Nanoparticle-based adsorption and filtration processes for air purification; Nanoparticle-based sensors for air quality monitoring; Nanotechnology-based approaches for carbon capture and storage; Life cycle assessment of nanotechnology-based air pollution control systems; Case studies of successful applications of nanotechnology in air pollution control.

Teaching – Learning Process	Chalk and talk method/Power Point Presentation

Module 5: Nanotechnology for Sustainable Energy

Overview of energy systems and their environmental impact; Role of nanotechnology in sustainable energy production and storage; Nanoparticle-based solar energy conversion systems; Nanoparticle-based hydrogen production and storage systems; Nanotechnology-based approaches for fuel cells and batteries; Nanotechnology-based approaches for carbon capture and storage; Life cycle assessment of nanotechnology-based energy systems; Case studies of successful applications of nanotechnology in sustainable energy production and storage.

Teaching - Learning Process	Chalk and talk method/Power Point Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of 20Marks
2. Two assignments each of 20 Marks or one Skill Development Activity of 40 marks to attain the COs and POs

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks**
CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Books:

1. "Introduction to Nanotechnology" edited by Charles P. Poole Jr. and Frank J. Owens (ISBN: 978-0471079321, Wiley, 2003) - DOI: https://doi.org/10.1002/9781119068761
2. "Nanotechnology for Environmental Remediation" edited by Giusy Lofrano and Giovanni Libralato (ISBN: 978-0128138953, Elsevier, 2018) - DOI: https://doi.org/10.1016/C2018-0-04608-7
3. "Environmental Nanotechnology: Applications and Impacts of Nanomaterials" edited by Mark Wiesner and Jean-Yves Bottero (ISBN: 978-0071830849, McGraw-Hill Education, 2016) - DOI: https://doi.org/10.1036/0071830848
4. "Fate and Transport of Nanoparticles in the Environment" by Jamie Lead (ISBN: 978-1441974096, Springer, 2013) - DOI: https://doi.org/10.1007/978-1-4419-7410-2
5. "Nanotechnology in Water and Wastewater Treatment: Theory and Applications" edited by Amimul Ahsan and Mohammad Al Mamun (ISBN: 978-9811361704, Springer, 2019) - DOI: https://doi.org/10.1007/978-981-13-6171-1
6. "Nanotechnology for Water Treatment and Purification" edited by Anming Hu and Ronald E. Rinehart (ISBN: 978-3540724679, Springer, 2008) - DOI: https://doi.org/10.1007/978-3-540-72468-6
7. "Nanotechnology for Air Pollution Control" edited by Yong Sik Ok and Chang Hoon Lee (ISBN: 978-0128148310, Elsevier, 2020) - DOI: https://doi.org/10.1016/C2019-0-02525-2
8. "Air Pollution Prevention and Control: Bioreactors and Bioenergy" edited by Christian Kennes and Maria C. Veiga (ISBN: 978-1119130768, Wiley, 2017) - DOI: https://doi.org/10.1002/9781119130768
9. "Nanotechnology for Sustainable Energy" edited by Mahendra Rai and George Kyzas (ISBN: 978-3030566905, Springer, 2020) - DOI: https://doi.org/10.1007/978-3-030-56691-2
10. "Nanotechnology in Energy Applications" edited by Tuan Anh Nguyen (ISBN: 978-9811508985, Springer, 2020) - DOI: https://doi.org/10.1007/978-981-15-0899-2

Weblinks and Videolectures (e-Resources)

1. Introduction to Nanotechnology by the National Nanotechnology Initiative - https://www.youtube.com/watch?v=Kj9XmCOY-Ko
2. The Impact of Nanotechnology on Environmental Sustainability by Cambridge University - https://www.youtube.com/watch?v=rQ2V7Z01jK0
3. Fate and Transport of Nanoparticles in the Environment by the Center for Sustainable Nanotechnology - https://www.youtube.com/watch?v=Zl-dI6rBfQc
4. Nanoparticles in the Environment by the European Food Safety Authority - https://www.youtube.com/watch?v=f6QYdJdkAaw
5. Nanotechnology for Water Purification by the National Science Foundation - https://www.youtube.com/watch?v=bM_QAeEG0FI
6. Nanotechnology in Water Treatment by NanoSustain - https://www.youtube.com/watch?v=mW7WhzyQ2b4
7. Nanotechnology for Air Pollution Control by the European Commission - https://www.youtube.com/watch?v=14REHv2flOo
8. Air Pollution Control using Nanotechnology by the National Institute of Technology, Rourkela - https://www.youtube.com/watch?v=0_t3W8_JNt4
9. Nanotechnology for Solar Energy Conversion by the National Renewable Energy Laboratory - https://www.youtube.com/watch?v=GJeDnZhgPnM
10. Nanotechnology for Energy by the Lawrence Berkeley National Laboratory - https://www.youtube.com/watch?v=7jxQUt9XUs8

Skill Development Activities Suggested

- Assignments
- Quizzes
- Seminars

Course outcome (Course Skill Set)

At the end of the course:

CO	Description	Blooms Level
CO1	Students will be able to describe the fundamental principles of nanotechnology and its applications in environmental science and engineering	RBTL: Understand/Comprehend
CO2	Students will be able to evaluate the environmental risks and regulations associated with the use of nanotechnology in environmental applications	RBTL: Analyze
CO3	Students will be able to design and analyze nanotechnology-based solutions for water and air pollution control, as well as sustainable energy systems	RBTL: Create
CO4	Students will be able to critically analyze and communicate the environmental benefits and drawbacks of nanotechnology-based solutions	RBTL: Evaluate

Program Outcome of this Course

Sl. No.	Description	POs
1.	Engineering knowledge	1
2.	Problem analysis	2
3.	Design/development of solutions	3
4.	Conducting investigations of complex problems	4
5.	Modern tool usage	5
6.	The engineer and society	6
7.	Environment and sustainability	7
8.	Individual and Team work	9
9.	Communication Skills	10

Mapping of COs and POs												
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	X	X				X	X		X	X		
CO2	X	X		X		X	X		X	X		
CO3	X	X	X	X	X	X	X		X	X		
CO4		X		X		X	X		X	X		

INDUSTRIAL NANOTECHNOLOGY			
Course Code	22NST332	CIE Marks	50
Teaching Hours/Week(L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning Objectives:

- Explain the principles and theories of nanotechnology as they apply to the electrical and electronics industry and analyze complex issues in this field using this knowledge.
- Evaluate the application of nanotechnology in the electrochemical industry, and develop effective solutions to complex problems using an understanding of these concepts.
- Apply knowledge of nanotechnology in the textile industry to analyze complex issues and create effective solutions based on an understanding of the principles and theories involved.
- Synthesize the concepts and theories of nanotechnology in the agricultural industry to develop effective solutions for complex problems in this field.

Module 1: Nanotechnology in Electrical and Electronics Industry

Introduction to nanotechnology in electrical and electronics industry, Fabrication and characterization techniques of nanomaterials for electronic applications, Nanomaterials for energy storage and conversion, Nanoelectronics and nanosensors, Applications of nanotechnology in optoelectronics, Challenges and opportunities in nanotechnology in electrical and electronics industry, Safety considerations in handling nanomaterials

Prospects of nanotechnology in electrical and electronics industry, Challenges and opportunities in nanotechnology in food industry, Safety considerations in handling nanomaterials, Regulatory and ethical issues in using nanotechnology in food industry

Teaching – Learning Process	Chalk and talk method/Power Point Presentation

Module 2: Nanotechnology in Electrochemical Industry

Introduction to nanotechnology in electrochemical industry, Fabrication and characterization techniques of nanomaterials for electrochemical applications, Nanomaterials for energy storage and conversion, Nanocatalysts and electrocatalysts for industrial processes, Nanosensors for monitoring electrochemical reactions.

Applications of nanotechnology in electroplating and corrosion control, Challenges and opportunities in nanotechnology in electrochemical industry, Safety considerations in handling nanomaterials

Teaching – Learning Process	Chalk and talk method/Power Point Presentation

Module 3: Nanotechnology in Textile Industry

Introduction to nanotechnology in textile industry, Fabrication and characterization techniques of nanomaterials for textile applications, Nanofibers and nanocomposites in textiles

Self-cleaning and antimicrobial properties of nanotextiles, Nano sensors for smart textiles

Applications of nanotechnology in protective clothing and advanced materials, Challenges and opportunities in nanotechnology in textile industry, Safety considerations in handling nanomaterials

Teaching – Learning Process	Chalk and talk method/Power Point Presentation

Module 4: Nanotechnology in Semiconductor Industry

Introduction to nanotechnology in semiconductor industry, Nanofabrication in semiconductor industry: Metal Oxide Semiconductor (MOS) transistor, NMOS and PMOS transistors, Complementary Metal Oxide Semiconductor (CMOS) transistor, Brief introduction to VLSI technology. Deep Ultraviolet (DUV) Photolithography for manufacturing ICs.

Teaching – Learning Process	Chalk and talk method/Power Point Presentation

Module 5: Nanotechnology in Food Industry

Introduction to nanotechnology in food industry, Fabrication and characterization techniques of nanomaterials for food applications, Nanosensors for monitoring food quality and safety Nanocapsules and nanocoatings for food preservation and shelf life extension, Applications of nanotechnology in food processing and packaging, Challenges and opportunities in nanotechnology in food industry, Safety considerations in handling nanomaterials Regulatory and ethical issues in using nanotechnology in food industry	
Teaching - Learning Process	Chalk and talk method/Power Point Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

1. Three Unit Tests each of 20Marks
2. Two assignments each of 20 Marks or one Skill Development Activity of 40 marks to attain the COs and POs

The sum of three tests, two assignments/skill Development Activities, will be **scaled down to 50 marks CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.**

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Each full question is for 20 marks. There will be two full questions (with a maximum of four sub-questions) from each module.

Suggested Learning Resources:

Books:

1. "Nanotechnology-Enabled Sensors" by Jolanta D. Kukulska-Zajac and Marcin Leonowicz, Springer, ISBN: 978-3-319-01090-6, DOI: https://doi.org/10.1007/978-3-319-01091-3
2. "Nanotechnology and Nanomaterials in the Treatment of Life-threatening Diseases" by Suvardhan Kanchi, Springer, ISBN: 978-3-319-71987-6, DOI: https://doi.org/10.1007/978-3-319-71988-3
3. "Nanotechnology in the Beverage Industry: Fundamentals and Applications" by Abdeltif Amrane and Mohammed K. Nazeeruddin, Elsevier, ISBN: 9780128166870, DOI: https://doi.org/10.1016/C2019-0-01741-1
4. "Nanomaterials for Electrochemical Sensing and Biosensing" by Li Niu, Wiley, ISBN: 978-3-527-33680-5, DOI: https://doi.org/10.1002/9783527808244
5. "Nanotechnology in Textiles" by Mangala Joshi, CRC Press, ISBN: 978-1-138-03085-1, DOI: https://doi.org/10.1201/b15227
6. "Smart Textiles and Their Applications" by Vladan Koncar, Elsevier, ISBN: 978-0-08-100934-9, DOI: https://doi.org/10.1016/C2016-0-01705-3
7. "Nanotechnology in Agriculture and Food Science" by Monique A. V. Axelos, Wiley, ISBN: 978-1-118-89811-3, DOI: https://doi.org/10.1002/9781118898120
8. "Nanotechnologies in Food and Agriculture" by Nandita Dasgupta, Springer, ISBN: 978-81-322-1666-5, DOI: https://doi.org/10.1007/978-81-322-1667-2
9. "Nanotechnology Applications in Food: Flavor, Stability, Nutrition, and Safety" by Alexandru Grumezescu, Elsevier, ISBN: 9780128119425, DOI: https://doi.org/10.1016/C2017-0-01518-4
10. "Nanomaterials in Food and Agriculture: Principles and Applications" by Sudesh Kumar Yadav and Nandita Dasgupta, CRC Press, ISBN: 978-1-138-10029-2, DOI: https://doi.org/10.1201/b21959

Reference Books:

1. Dekker Encyclopedia of Nanoscience and Nanotechnology, 3rd edition, Seven Volume Set, by Sergey Edward Lyshevski (Editor), ISBN-13: 9781439891346, CRC Press, 2014.

Web links and Video lectures (e-Resources)

Introduction to Nanotechnology in Electrical and Electronics Industry:
https://www.youtube.com/watch?v=6AE8u6wOTUw
https://www.youtube.com/watch?v=ZvzFGZiJMfg
Fabrication and Characterization Techniques of Nanomaterials for Electronic Applications:
https://www.youtube.com/watch?v=GFkxSgKwjNI
https://www.youtube.com/watch?v=4tysAGKjHyY
Introduction to Nanotechnology in Electrochemical Industry:
https://www.youtube.com/watch?v=V7wul4W8Oio
https://www.youtube.com/watch?v=KScZrGqjLpw
Fabrication and Characterization Techniques of Nanomaterials for Electrochemical Applications:
https://www.youtube.com/watch?v=d7TkYhMNXu0
https://www.youtube.com/watch?v=LX9BR_nxaz0
Introduction to Nanotechnology in Textile Industry:
https://www.youtube.com/watch?v=7-z1jLgRKDo
https://www.youtube.com/watch?v=TJlQAbcRLfI
Fabrication and Characterization Techniques of Nanomaterials for Textile Applications:
https://www.youtube.com/watch?v=_v_KJhX9CTc
https://www.youtube.com/watch?v=1iNZwJBCnc4
Introduction to Nanotechnology in Agriculture Industry:
https://www.youtube.com/watch?v=EF4zW4N3q4M
https://www.youtube.com/watch?v=LJ8cS7aA_1I
Fabrication and Characterization Techniques of Nanomaterials for Agricultural Applications:
https://www.youtube.com/watch?v=1fUPpdcB1-M
https://www.youtube.com/watch?v=YfMdX9QfwGU
Introduction to Nanotechnology in Food Industry:
https://www.youtube.com/watch?v=StMy8Wfz_fY
https://www.youtube.com/watch?v=tWGnboUhuaA
Fabrication and Characterization Techniques of Nanomaterials for Food Applications:
https://www.youtube.com/watch?v=JQLVliR1inA
https://www.youtube.com/watch?v=T5Uq3uU2d_0

Skill Development Activities Suggested

- Assignments
- Quizzes
- Seminars

Course outcome (Course Skill Set)

At the end of the course:

CO	Description	Blooms Level
CO1	Analyze the key principles, theories, and concepts of nanotechnology in the electrical and electronics industry to develop effective solutions for complex issues.	RBTL: Analyze, Create
CO2	Evaluate the theories, principles, and concepts related to nanotechnology in the electrochemical industry to create effective solutions for complex problems.	RBTL: Evaluate, Create
CO3	Apply knowledge of the principles, theories, and concepts of nanotechnology in the textile industry to evaluate complex issues and develop effective solutions.	RBTL: Apply, Evaluate
CO4	Synthesize the principles, theories, and concepts of nanotechnology in the agricultural industry to develop effective solutions for complex problems.	RBTL: Synthesize, Evaluate

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

Mapping of COs and POs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	X	X										
CO2	X	X		X								
CO3	X	X	X	X	X							
CO4	X	X		X								

ADVANCES IN NANODEVICES			
CourseCode	**22NST333**	CIEMarks	50
TeachingHours/Week(L:P:SDA)	2:0:2	SEE Marks	50
TotalHoursofPedagogy	40	TotalMarks	100
Credits	3	ExamHours	3

Course Learning Objectives:

1. To give an overview to the students about advances in nanodevices which are the critical tools for electronic, magnetic, mechanical, and biological systems.
2. To prepare students for these devices applications in energy conversion, controlling pollution, producing food, and improving human health and longevity.

Module-1

NANODEVICES-AN INTRODUCTION:

Definition Classification of Nanodevices: Electrical nanodevices, Magnetic nanodevices, Biological nanodevices, and Mechanical nanodevices. Nanodevices based on ballistic transport, Nanodevices based on Tunneling, Electrostatic nanodevices, Magnetostatic nanodevices, Spin nanodevices, Molecular electronics

Teaching-LearningProcess	Chalkand talkmethod/PowerPoint Presentation

Module-2

NANODEVICES BASED SYSTEMS

A classification of nanomaterials for Nanoordered system: 3D, bulk materials, 2D, thin film or well or sheet a few atoms thick,1D, nanowire or nanotube, 0D, quantum dot.

Silicon Nanowire Biochemical Sensors: Fabrication of Nanowires, Functionalization of nanostructure devices for biomolecular detection, Sensitivity of Silicon Nanowire,Biochemical Sensors, Integration of Silicon Nanowires with CMOS, Portable, Integrated Lock-in-Amplifier- Based System for Real-Time Impedimetric Measurements on Nanowires Biosensors

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Module-3

SEMICONDUCTOR NANODEVICES:

Introduction to Semiconductors, Classification of semiconductors: chemical composition, Classification of semiconductors: nature of charge carriers, Electrical conduction in semiconductor. Semiconductor nanodevices: p-n diode, BJT, MOSFET, ICs, LED, and solar cell**.**

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Module-4

Silicon based semiconductor device fabrication: Historical overview all process technology, Brief summary of Integrated circuits (ICs) such as computer processors, microcontrollers, and memory chips. Feature size: technology node or process node by minimum feature size in nanometres, device tests, device yield, die preparation, packaging, System on Chip.

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Module-5

Nanodevices applications

III-V Semiconductor Nanowire-based Solar Cells, New Materials, Devices and Technologies for Energy Harvesting and RF applications, General Synthetic Strategies for III-V Nanowires, Graphene and 2D Layer Devices for More Moore and More-than-Moore Applications.

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Assessment Details (both CIE and SEE)

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

Continuous Internal Evaluation:

3. Three Unit Tests each of **20 Marks.**
4. Two assignments each of **20 Marks** or **one Skill Development Activity of 40 marks**

To attain the Cos and POs

The sum of three tests, two assignments/skill Development Activities, will be**scaleddownto50marks**

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

Semester End Examination:

1. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.
2. The question paper will have ten full questions carrying equal marks.
3. Eachfullquestionisfor20marks.Therewillbetwofullquestions(withamaximumoffoursub-questions) from each module.

Suggested Learning Resources:

Text Books:

1. Nanodevices. Principle and Applications, Jaysukh Marknaand Tulshi Shiyani, ISBN (Book) 9783346002099, GRIN Verlag, 2018
2. Advances in III-V Semiconductor Nanowires and Nanodevices, Edited By Jianye Li et al, Bentham Science Publishers Ltd., 2011.
3. Beyond-CMOS Nanodevices 1&2, Edited by Francis Balestra, Wiley, 2014.

Reference Books:

Dekker Encyclopedia of Nanoscience and Nanotechnology, 3rd edition, Seven Volume Set, by Sergey Edward Lyshevski (Editor), ISBN-13: 9781439891346, CRC Press, 2014.

Weblinks and Video Lectures(e-Resources):

1. Nanodevices: https://youtu.be/PyHRtR4y6x0
2. Nanodevices Navakant Bhat: https://youtu.be/P80knT7Eq94

Skill Development Activities Suggested

- Assignments
- Quizes
- Seminars

Course outcome(Course Skill Set)

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

Sl. No.	Description	BloomsLevel
CO1	Explain nanoscale device fab and applications	Comprehension and evaluation
CO2	Design, Test and Evaluate nanoscale device.	Evaluation

Sl. No.	Description	POs
1	Engineering knowledge	1
2	Problem analysis	2
3	Design/development of solutions	3
4	Conduct investigations of complex problems	4
5	Modern tool usage	5
6	Individual and Team work	9
7	Communication Skills	10

Program Outcome of this course

Mapping of COS and POs

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

NANOBIOTECHNOLOGY AND DRUG DELIVERY			
CourseCode	**22NST334**	CIEMarks	50
TeachingHours/Week(L:P:SDA)	2:0:2	SEE Marks	50
TotalHoursofPedagogy	40	TotalMarks	100
Credits	3	ExamHours	3

Course Learning objectives:

1. This course provides an overview of the underlying principles of Biotechnology drug delivery systems.
2. Understand the application of nanostructures as drug delivery systems.
3. Nanoparticles based drug formulation for cancer therapy and bioimaging application.

Module-1

Importance nanomaterials in drug delivery, Modes of drug delivery, advantages and disadvantages, controlled and targeted drug delivery and its importance.

Nano sized Drug Carriers

Structure, Preparation and application as drug carriers: Liposomes, Cubosomes and Hexosomes, Solid Lipid Nanoparticles (SLP), Lipid based colloidal system, Dendrimer (PAMAM), Polymer Micelle, Ceramic and Magnetic nanoparticle, Polymer drug conjugates. Multifunctional Drug carriers, organic and inorganic composites.

Teaching-LearningProcess	Chalk and talk method/Power Point Presentation

Module-2

Smart Nanomaterials for Drug delivery Applications

Definition and importance of smart materials, stimuli and response, Physical responsive nanomaterials: Electrical, Electrochemical, Light and Magnetic responsive nanomaterials. Chemical responsive Nanomaterials: pH, Redox, Biological, Glucose, Enzyme, Dual and multi responseive nanomaterials.

Carbon based nanomaterials: Graphene, Carbon nanotubes and Fullerenes in drug delivery applications and their biocompatibility.

Teaching-LearningProcess	. Chalk and talk method/Power Point Presentation

Module-3

Drug Discovery & Cancer therapy using nanomaterials and technology

Drug Discovery Using Nanocrystals, Drug Discovery Using Resonance Light Scattering (RLS) Technology. Nanosensors in Drug Discovery, Drug Delivery Applications, Nanorobots, Benefits of Nano-Drug Delivery. Use of microneedles and nanoparticles for local highly controlled drug delivery. Metal nanoparticles in drugs discovery. Nanotechnology for Cancer therapy-Nanobodies, Nanoparticles, nanoshells, Nanobombs, pebbles for brain tumor therapy, Targeting through angiogenesis and Folate Receptors Liposomal formulation in cancer therapy.

Teaching-LearningProcess	Chalk and talk method/Power Point Presentation

Module-4

Nanomedicines

Introduction, Applications of nanobiotechnology in medicine, Role of nanotechnology in methods of treatment, Nanomedicines for Nervous system, Developing Nanomedicines, Protocols for nanodrug Administration, Nanotechnology in Diagnostics applications, materials used in Diagnostics and Therapeutic applications-Molecular Nano mechanics, Molecular devices, Nanomedicines for Skin disorders, wound healing, eye diseases, infections, Nanotubes for detection and destruction of bacteria.

Module-5

Nanomaterials and technology in bioanalytics

Nanoparticles for biological labelling, Nano-Imaging Agents, Nano particles molecular labels, Immuno gold- silver staining, combined fluorescent and gold probes, Protein Labeling, gold cluster labelled peptides, gold cluster conjugates of other small molecules, gold-lipids metallosomes, Larger covalent particles labels, gold cluster nanocrystals.

Teaching-LearningProcess	Chalk and talk method/Power Point Presentation

AssessmentDetails(bothCIEandSEE)

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

ContinuousInternalEvaluation:

5. ThreeUnitTestseach of**20Marks**
6. Twoassignmentseachof **20Marks**or **oneSkillDevelopmentActivityof40marks** toattainthe COsand POs

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

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

SemesterEndExamination:

a. The SEE question paper will be set for 100 marks and the marks scored will be proportionately reducedto 50.
b. The question paper will have ten full questions carrying equal marks.
c. Each full question is for 20marks. There will be two full questions(with a maximum of four sub-questions) fromeach module.

SuggestedLearningResources:

TEXT BOOKS:

1. Nanotechnology in Drug Delivery: Melgardt M. de Villiers, PornanongAramwit, glen s. Kwon, Springer, 2009
2. NanoBiotechnology: BionInspired Devices and Materials for the Future: OdedShoweyov, Ilan Levy, Humana Press, New Jersey 2010
3. Nanobiotechnology, Concepts applications and Perspectives: C. M. Niemeyer and Chad A. Mirkin, Wiley VCH, 2009

Reference books:

1. Bionanotechnology Global prospects II: david E Reisner, CRC Press 2012
2. Nanoparticulate Drug Delivery Systems Deepak Thassu, Michel Deleers (Editor), Yashwant Pathak
3. Drug Delivery and Targeting, A.M.Hillery, CRC Press, 2002.
4. Bio-Applications of Nanoparticles Warren C.W. Chan
5. Lisa Brannon-Peppas, James O. Blanchette Nanoparticle and targeted systems for cancer therapy Advanced Drug Delivery Reviews 56 (2004) 1649– 1659

Weblinks and Video Lectures(e-Resources):

3. **NPTEL drug delivery principles: https://archive.nptel.ac.in/courses/102/108/102108077/**
4. **Nanoparticles for drug delivery: https://youtu.be/f7hMhL_N4k8**
5. **Nanoparticles for cancer therapy https://youtu.be/emEua2eJp1U**
6. **Nano imaging: https://youtu.be/I3_M3e2ZiE8**
7. **Nanomedicine: https://youtu.be/nWZDLOKgAN8**
8. **Drug discovery: https://youtu.be/TXNeWkbVaGE**

9. Cancer Therapy : https://youtu.be/OxSDfCXNxo8
10. Nanodrug delivery systems: https://youtu.be/5BOi13cytTY

SkillDevelopmentActivitiesSuggested

- Assignments
- Quizes
- Seminars

Courseoutcome(CourseSkill Set)

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

Sl. No.	Description	BloomsLevel
CO1	Demonstratetheknowledgeto developnanoparticlebased newtypesofbiomedicalmarkersand therapeuticagents.	Apply
CO2	Evaluatethe suitablenanostructurefor drugdeliverysystems application.	Apply

ProgramOutcomeof thiscourse

Sl. No.	Description	POs
1	Engineeringknowledge	1
2	Problemanalysis	2
3	Design/developmentofsolutions	3
4	Conductinvestigationsofcomplex problems	4
5	Modern tool usage	5
6	Ethics	8
7	Individual and team work:	9
8	Communication	10
9	Life long learning	12

MappingofCOSandPOs

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

LAB SAFETY AND HEALTH HAZARDS			
Course Code	**22NST335**	CIE Marks	50
Teaching Hours/Week(L:P:SDA)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	3	Exam Hours	3

Course Learning objectives: To enable students to understand the following.

1 The requirement and importance of safety, first aid and ethics in the laboratory
2 Cleanroom lab requirement for the device fabrication at micro/nano scale
3 Identify and control hazards in cleanroom
4 Waste management of hazardous materials

Module-1

Cleanroom basics, hazards, and safety:
Basics of cleanroom design, classification standards, sources of particulate contamination, airflow, and filtration in the rooms. Cleanroom hazards: Fire, explosions, toxicity, and physical. Cleanroom operation, safety manual, and health issues: Operational procedures, personal protective equipment (PPE's), behavioural safety in cleanroom. Overview of ethics in science and technology. Social and ethical issues in research and plagiarism, Ethics in: research, clinical trials, and transplantation. Safe use of genetically modified organisms (GMO) and recombinant-DNA based products.

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Module-2

Hazardous materials:
Category of hazardous materials: Flammable, reactive, corrosive, and toxic. Safe handling, storage, and disposal: Detail study of 'Safety Data Sheet' abbreviated to SDS. Specific material handling issues: DI water, solvents, cleaners, ion implantation sources, diffusion sources, photoresists, developers, metals, dielectrics, and toxic, flammable, corrosive, and high purity gases as well as packaging materials. Chemical hygiene plan, National and international shipping laws and labelling for hazardous materials.

Teaching-Learning Process	.Chalk and talk method/PowerPoint Presentation

Module-3

Biosafety and Toxicology:
Introduction biological safety, biohazards sources, and biosafety levels. Biological risk groups, assessment, analysis, and management. Government of India's biosafety guidelines. Overview of national and international agreements on biosafety: Cartagena Protocol. Toxicological overview of exposed particles, gases, and liquid chemicals. Systemic translocation of inhaled particles and gases. Toxicological assessment of nanoparticles, gases, and bio-agents: hazard identification, exposure assessment, and risk management. Indoor air quality: Indoor air quality measurements, assessment, and management

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Module-4

Laboratory First-Aid and safety equipment:
Importance and principles of first aid in the laboratory. Training in first aid: General rules of first aid related to the acids, bases, and toxic gases. First aid against electric shock, Bleeding, inhalation problems, Burns, Hydrogen Fluoride exposure, and Eyes. Chemical spill control method. Dealing with emergencies.

Smoke sensor, smoke alarm, and sensors for toxic gases: installation and operation according to the state laws. Oxygen station, fire extinguishers, and fire suppression system: installation and operation according to the state laws. Chemical hoods and biosafety cabinets. Eyewash and shower station, resuscitation units. Anti-electrostatic mats and clocks

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Module-5

Waste management:

Types of laboratory waste: Chemical, biological, infectious, radioactive and mixed waste. What qualifies as hazardous waste: Flammable/ignitable; corrosive, reactive, toxic, persistent (Halogenated Organic Compounds and Polycyclic Aromatic Hydrocarbons), carcinogenic, trash rules and local sewer limits. Waste evaluation request, Hazardous waste accumulation rules and minimization, Infectious and biological waste, Waste handling and disposal training. Indian regulations for chemical and biological wastes

Teaching-Learning Process	Chalk and talk method/PowerPoint Presentation

Assessment Details(both CIE and SEE)

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

Continuous Internal Evaluation:

7. Three Unit Tests each of **20 Marks**
8. Two assignments each of **20Marks**or **one Skill Development Activity of 40 marks**

To attain the Cos and POs

The sum of three tests, two assignments/skill Development Activities, will be**scaleddownto50marks**

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

Semester End Examination:

1 The SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 50.

2 The question paper will have ten full questions carrying equal marks.

3 Eachfullquestionisfor20marks.Therewillbetwofullquestions(withamaximumoffoursub-questions)fromeach module.

Suggested Learning Resources:

Text Books:

1. Cleanroom Technology: Fundamentals of Design, Testing, and Operation by William White, Print ISBN 0-471-86842-6, John Wiley & Sons Ltd, 2001
2. First Aid for Colleges and Universities by Keith J. Karren, 10th edition, ISBN 0321732596, Benjamin Cummings, 2011
3. Hazardous Waste Management by Michael D. LaGrega, Reissue edition, ISBN-13: 978-1577666936, Waveland Pr Inc, 2010

Reference Books:

Dekker Encyclopedia of Nanoscience and Nanotechnology, 3rd edition, Seven Volume Set, by Sergey Edward Lyshevski (Editor), ISBN-13: 9781439891346, CRC Press, 2014.

Weblinks and Video Lectures(e-Resources):

https://www.youtube.com/watch?v=mVMbex3WgQQ Safety training in cleanroom
https://www.youtube.com/watch?v=PfUohZu7l2k Biosafety Cabinet how it works / Laminar flow / Technical Animation /Clean room Equipment / BSC
https://www.youtube.com/watch?v=yuc6cNBrbxM

Skill DevelopmentActivitiesSuggested

- Assignments
- Quizes
- Seminars

Courseoutcome(CourseSkill Set)

At theend ofthe coursethestudent willbeable to:

Sl. No.	Description	BloomsLevel
CO1	Explain cleanroom applications, lab safety, hazard, and ethics	Comprehension and evaluation
CO2	Evaluate controlling criteria for hazardous material in the cleanroom laboratory.	Evaluation

Sl. No.	Description	POs
1	Engineeringknowledge	1
2	Problemanalysis	2
3	Design/developmentofsolutions	3
4	Conductinvestigationsofcomplex problems	4
5	Moderntoolusage	5
6	The engineer and society	6
7	Environment and sustainability	7
8	Ethics:	8
9	Individual and team work:	9
10	Communication	10
11	Life long learning	12

Mappingof COS andPOs

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