MTech in Nanotechnology

Semester- I

APPLIED MATHEMATICS			
Course Code	22INT11	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.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

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Suggested Learning Resources:

Books

1. 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/
- Sampling Theory: https://www.youtube.com/watch?v=ULWljMQo0Pg

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	

SYNTHESIS AND PROCESSING TECHNIQUES			
Course Code	**22INT12**	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. 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:

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:

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:

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)

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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 FOR NANOSTRUCTURES			
Course Code	**22INT13**	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

Milestones in nanoscience and nanotechnology, Nanostructures and quantum physics, Layered nanostructures and superlattices, Nanoparticles and nanoclusters, Carbon-based nanomaterials. Wave-particle duality: Blackbody radiation, interaction of radiation with matter, photoelectric effect, Compton effect, wave-particle duality, De-Broglie's hypothesis, uncertainty relations, wave function, Schrodinger equation, Operators.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Solutions of Schrodinger Equations

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-3

Approximate methods of finding quantum states:

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Quantum states in atoms and molecules:

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5

Quantization in nanostructures:

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

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Assessment Details (both CIE and SEE)

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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:

Books

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

Web links and Video Lectures (e-Resources):

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

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

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

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

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	**22INT14**	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)

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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:

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										

Nanomaterials and their Properties			
Course Code	**22INT15**	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

Introduction to nanoscience and nanotechnology:
History, background scope and interdisciplinary nature of nanoscience and nanotechnology, scientific revolutions. Definition of Nanometer, Nanomaterials, and Nanotechnology. Concepts of nanotechnology - size dependent phenomena, surface to volume ratio, atomic structure, molecules and phases, energy at the nanoscale molecular and atomic size. Misnomers and misconception of nanotechnology, importance of nanoscale materials and their devices.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-2

Classification of Nanostructures:
Zero dimensional, one-dimensional and two dimensional nanostructure materials. Clusters of metals, semiconductors, ceramics and nanocomposites. Size effect on shapes, Quantum dots, Nanorods, nanowires, nanotubes, nanosheets, nanocones, Nanotetrapods, Nanoflowers, nanobrushes, nano and mesopores, Core-Shell nanoparticles.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-3

Types of Nanomaterial:
Metal nanoparticles, Ceramics nanomaterials, Semiconductor nanoparticles, Metal oxides nanoparticles, Carbon based nanostructures. Acomparison with respective bulk materials; Organic semiconductors Importance of these nanomaterials and their applications

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-4

Properties of Nanomaterials:
Mechanical properties, Nano size effect on strength, fracture toughness and fatigue behaviour. Bulk Properties of Materials, electrical conductivity, Dielectric properties, Thermal properties, thermal conductivity, heat capacity. Magnetic properties, Magnetic materials, domains in Magnetic materials.

Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation

Module-5

Electronic and Optical Properties:
Electronic structure of Nanomaterials, magic numbers, Fermi surface, Size effect on Electron-Phonon Coupling, Size effect on physical properties. Optical properties, Optoelectronic properties of bulk and nanostructures, relation between optical properties and electronic structure of nanomaterials – Catalytic property Catalysis by Gold Nanoparticles

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:

TEXT BOOKS:

1. Edward L. Wolf, "Nanophysics and Nanotechnology - An Introduction to Modern Concepts in Nanoscience" Second Edition, John Wiley & Sons, 2006.
2. M.S. Ramachandra Rao, Shubra Singh, Nanoscience and Nanotechnology: fundamentals to Frontiers, Wiley 2013
3. Nanostructures and Nanomaterials synthesis, properties and applications, g. Cao, Imperial College press 2004.

References:

1. Masuo Hosokawa, Kiyoshi Nogi, Makio Naito, Toyokazu Yokoyama Nanoparticle Technology Handbook, Elsevier Science, 2007
2. Nanotechnology – Basic Science & Emerging Technologies, Chapman & Hall/CRC 2002
3. Nanomaterials – A. K. Bandyopadhyay, New Age International Publishers, 2nd Edition, 2010

Web links and Video Lectures (e-Resources):

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

Skill Development Activities Suggested

- Quizzes
- Assignments
- Seminars

Course outcome (Course Skill Set)

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

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

Program Outcome of this course

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

Mapping of COS and POs

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

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Common To All M.Tech.

Research Methodology and IPR			
Course Code	**22RMI16**	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: •			
Module-1			
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation		
Module-2			
Teaching-Learning Process	. Chalk and talk method / PowerPoint Presentation		
Module-3			
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation		
Module-4			
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation		
Module-5			
Teaching-Learning Process	Chalk and talk method / PowerPoint Presentation		

Common To All M.Tech.

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Synthesis and property measurement Lab			
Course Code	**22INTL17**	CIE Marks	
Teaching Hours/Week (L:T:P: S)		SEE Marks	
Credits		Exam Hours	

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	
8	Photocatalytic degradation property analysis of TiO_2 nanoparticles
9	Preparation of cadmium sulphide nanoclusters and its spectral studies
10	Synthesis of silver nanoparticles by reduction method using plant extracts
11	
12	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 8^{th} week of the semester and the second test shall be conducted after the 14^{th} 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:

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Semester- 2

Design and Fabrication Techniques			
Course Code	**22INT21**	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.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

TEXT BOOKS:

1. 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
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											
CO2	x	x	x	x	x							
CO3	x											
CO4	x	x	x	x	x	x	x	x				x

Characterisation Techniques			
Course Code	**22INT22**	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
7	Determination of band gap of semiconductor nanomaterials by UV-Vis absorption spectra

8	**Magnetic characterisation of nanomaterials**
9	**Impedance measurement of nanomaterials**

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)

5. The question paper will be set for 100 marks and marks scored will be scaled down proportionately to 50 marks.
6. The question paper will have ten questions. Each question is set for 20 marks.
7. 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.
8. 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:

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

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

Web links and Video Lectures (e-Resources):

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

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											

Biomedical Nanotechnology			
Course Code	**22INT231**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)		SEE Marks	50
Total Hours of Pedagogy		Total Marks	100
Credits		Exam Hours	

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.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

TEXT BOOKS:

1. 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**

Nanotechnology and Environment			
Course Code	**22INT232**	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.
5. The students will have to answer five full questions, selecting one full question from each 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
- Cleanroom classifications: https://www.youtube.com/watch?v=IENbOfC4df8

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	**22INT233**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)		SEE Marks	50
Total Hours of Pedagogy		Total Marks	100
Credits		Exam Hours	

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.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

TEXT BOOKS:

1. 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	**22INT234**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)		SEE Marks	50
Total Hours of Pedagogy		Total Marks	100
Credits		Exam Hours	

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.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. 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	**22INT235**	CIE Marks	50
Teaching Hours/Week (L:P:SDA)		SEE Marks	50
Total Hours of Pedagogy		Total Marks	100
Credits		Exam Hours	

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.
4. Each full question will have a sub-question covering all the topics under a module.
5. The students will have to answer five full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. 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	**22INT241**	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:

-

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)

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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:

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
- Biosensors: Prof. S. K. Srivastava, IIT Roorkee: https://archive.nptel.ac.in/courses/115/107/115107122/

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 FOR NANOTECHNOLOGY			
Course Code	**22INT242**	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)

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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:

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	**22INT243**	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)

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

Semester End Examination:

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

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Suggested Learning Resources:

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	**22INT244**	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)

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1. Three Unit Tests each of **20 Marks**
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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	**22INT245**	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.
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. 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	**22INTL26**	CIE Marks	
Teaching Hours/Week (L:T:P: S)		SEE Marks	
Credits		Exam Hours	

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 8^{th} week of the semester and the second test shall be conducted after the 14^{th} 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

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