VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELAGAVI

Scheme of Teaching and Examinations and Syllabus

M.Tech. Nanotechnology (INT)

(Effective from Academic year 2020 - 21)

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
Scheme of Teaching and Examinations – 2020 - 21
M.Tech Nanotechnology (INT)
Choice Based Credit System (CBCS) and Outcome Based Education(OBE)

I SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours per Week			Examination				Credits
				Theory	Practical	Skill Development Activities (SDA)	Duration in hours	CIE Marks	SEE Marks	Total Marks	
1	PCC	20INT11	Applied Mathematics	03	--	02	03	40	60	100	4
2	PCC	20INT12	Quantum Mechanics for Nanostructures	03	--	02	03	40	60	100	4
3	PCC	20INT13	Nanomaterials and Properties	03	--	02	03	40	60	100	4
4	PCC	20INT14	Synthesis and Processing Techniques	03	--	02	03	40	60	100	4
5	PCC	20INT15	Carbon Based Nanostructures	03	--	02	03	40	60	100	4
6	PCC	20INTL16	Synthesis and Characterization Lab	--	04	--	03	40	60	100	2
7	PCC	20RMI17	Research Methodology and IPR	02	--	--	03	40	60	100	2
			TOTAL	**17**	**04**	**10**	**21**	**280**	**420**	**700**	**24**

Note: PCC: Professional core.

Skill development activities:
Students and course instructor/s to involve either individually or in groups to interact together to enhance the learning and application skills.
The students should interact with industry (small, medium and large), understand their problems or foresee what can be undertaken for study in the form of research/ testing / projects, and for creative and innovative methods to solve the identified problem.
The students shall
(1) Gain confidence in modelling of systems and algorithms.
(2) Work on different software/s (tools) to Simulate, analyse and authenticate the output to interpret and conclude. Operate the simulated system under changed parameter conditions to study the system with respect to thermal study, transient and steady state operations, etc.
(3) Handle advanced instruments to enhance technical talent.
(4) Involve in case studies and field visits/ field work.
(5) Accustom with the use of standards/codes etc., to narrow the gap between academia and industry.
All activities should enhance student's abilities to employment and/or self-employment opportunities, management skills, Statistical analysis, fiscal expertise, etc.

Internship: All the students have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination shall be conducted during III semester and the prescribed credit shall be counted for the same semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as fail in internship course and have to complete the same during the subsequent University examination after satisfying the internship requirements.

Note: (i) Four credit courses are designed for 50 hours Teaching – Learning process.
(ii) Three credit courses are designed for 40 hours Teaching – Learning process.

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II SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week			Examination				Credits
				Theory	Practical/ seminar	Skill Development Activities (SDA)	Duration in hours	CIE Marks	SEE Marks	Total Marks	
1	PCC	20INT21	Design and Fabrication Techniques	03	--	02	03	40	60	100	4
2	PCC	20INT22	Characterization Techniques	03	--	02	03	40	60	100	4
3	PCC	20INT23	Advanced & Smart Materials	03	--	02	03	40	60	100	4
4	PEC	20INT24X	Professional elective 1	04	--	--	03	40	60	100	4
5	PEC	20INT25X	Professional elective 2	04	--	--	03	40	60	100	4
6	PCC	20INTL26	Device Fabrication and CharacterizationLab	--	04	--	03	40	60	100	2
7	PCC	20INT27	Technical Seminar	--	02	--	--	100	--	100	2
TOTAL				**17**	**06**	**06**	**18**	**340**	**360**	**700**	**24**

Note: PCC: Professional core, PEC: Professional Elective.

Professional Elective 1		Professional Elective 2	
Course Code under 20INT24X	**Course title**	**Course Code under 20INT25X**	**Course title**
20INT241	Nanotechnology and Environment	20INT251	Nanoelectronics
20INT242	Nanocomposites and its applications	20INT252	MEMS and NEMS
20INT243	Nanobiotechnology	20INT253	Industrial Applications of Nanotechnology
20INT244	Surface Engineering of Nanomaterials	20INT254	Nanotechnology in Civil Engineering

Note:

1. Technical Seminar: CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide, if any, and a senior faculty of the department. Participation in the seminar by all postgraduate students of the same and other semesters of the programme shall be mandatory.

The CIE marks awarded for Technical Seminar, shall be based on the evaluation of Seminar Report, Presentation skill and Question and Answer session in the ratio 50:25:25.

2. Internship: All the students shall have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination shall be conducted during III semester and the prescribed credit shall be counted in the same semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as fail in internship course and have to complete the same during the subsequent University examination after satisfying the internship requirements.

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III SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week			Examination				Credits
				Theory	Practical/ Mini –Project/ Internship	Skill Development activities (SDA)	Duration in hours	CIE Marks	SEE Marks	Total Marks	
1	PCC	20INT31	Nanomaterials and Energy Systems	03	--	02	03	40	60	100	4
2	PEC	20INT32X	Professional elective 3	03	--	--	03	40	60	100	3
3	PEC	20INT33X	Professional elective 4	03	--	--	03	40	60	100	3
4	Project	20INT34	Project Work phase -1	--	02	--	--	100	--	100	2
5	PCC	20INT35	Mini-Project	--	02	--	--	100	--	100	2
6	Internship	20INTI36	Internship	(Completed during the intervening vacation of I and II semesters and /or II and III semesters.)			03	40	60	100	6
TOTAL				09	04	02	12	360	240	600	20

Note: PCC: Professional core, PEC: Professional Elective.

Professional elective 3		Professional elective 4	
Course Code under 20INT32X	**Course title**	**Course Code under 20INT33X**	**Course title**
20INT321	Modeling and Simulation in Nanotechnology	20INT331	Nanobioelectronics and Applications
20INT322	Nanotechnology in Diagnostics and Drug Delivery	20INT332	Micro-Nano Packaging
20INT323	Micro and Nanofluidics	20INT333	Advances in Nanodevices
20INT324	Nanotechnology for corrosion Science and Engineering	20INT334	Nanotechnolgy in Food and Agriculture

Note:

1. Project Phase-1: Students in consultation with the guide/co-guide if any, shall pursue literature survey and complete the preliminary requirements of selected Project work. Each student shall prepare relevant introductory project document, and present a seminar.

CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide if any, and a senior faculty of the department. The CIE marks awarded for project work phase -1, shall be based on the evaluation of Project Report,

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IV SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week		Examination				Credits
				Theory	Practical/ Field work	Duration in hours	CIE Marks	SEE Marks Viva voce	Total Marks	
1	Project	20INT41	Project work phase -2	--	04	03	40	60	100	20
			TOTAL	--	**04**	**03**	**40**	**60**	**100**	**20**

Project Presentation skill and Question and Answer session in the ratio 50:25:25.
SEE (University examination) shall be as per the University norms.
2. Internship: Those, who have not pursued /completed the internship shall be declared as fail in internship course and have to complete the same during subsequent University examinations after satisfying the internship requirements. Internship SEE (University examination) shall be as per the University norms.

Note:

1. Project Phase-2:

CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide, if any, and a Senior faculty of the department. The CIE marks awarded for project work phase -2, shall be based on the evaluation of Project Report subjected to plagiarism check, Project Presentation skill and Question and Answer session in the ratio 50:25:25.

SEE shall be at the end of IV semester. Project work evaluation and Viva-Voce examination (SEE), after satisfying the plagiarism check, shall be as per the University norms.

M.Tech., Nanotechnology
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2020 -2021)
SEMESTER - I

Course Title	**APPLIED MATHEMATICS**	**Code**	**20INT11**
Teaching Hours/Week (L:P:SDA)	3:0:2	CIE Marks	40
Total Number of Lecture Hours	40	Exam Marks	60
Credits	04	Exam Hours	03

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 01

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

Module 02

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.

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.

Probability Theory

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

Sampling Theory

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

Course Outcomes:

The Student will be able to

1. Comprehension of basic concepts will enable the students to apply mathematical models for solving problems in nanotechnology.
2. Solve system of linear equations using direct and iterative methods.
3. Apply the technique of least square approximation in solving inconsistent linear systems.
4. Describe the basic notions of discrete and continuous probability distributions.
5. Find out responses of linear systems using statistical and probability tools.
6. An ability to demonstrate a systematic knowledge of the mathematics for Nanotechnology applications.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.

- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

TEXT BOOKS/REFERENCES

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.

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 - 21) SEMESTER - I			
Course Title	**QUANTUM MECHANICS FOR NANOSTRUCTURES**	**Code**	**20INT12**
Teaching Hours/Week (L:P:SDA)	3:0:2	CIE Marks	40
Total Number of Lecture Hours	40	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
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.	10	L1, L2,
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.	10	L1, L2, L3
Module 3: Approximate methodsof finding quantum states: Stationary perturbation theory for a system with non-degenerate states and degenerate states. Non-stationary perturbation theory, quasi-classical approximation.	10	L1, L2, L3
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.	10	L1, L2, L3, L4
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	10	L1, L2, L3, L4

superlattice of quantum dots, three-dimensional superlattice of quantum dots.		

Course Outcomes:

The Student will be able to

1. Comprehension of basic concepts will enable the students to apply quantum mechanics for solving problems in nanotechnology.
2. An ability to demonstrate a systematic knowledge of the
3. computational modelling for Nanotechnology applications.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

TEXT 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.

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - I			
Course Title	**NANOMATERIALS AND PROPERTIES**	**Code**	**20INT13**
Teaching Hours/Week (L:P:SDA)	3:0:2	CIE Marks	40
Total Number of Lecture Hours	40	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
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.	08	L1, L2,
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.	08	L1, L2, L3
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.	08	L1, L2, L3, L4
4	**Properties of Nanomaterials:**	08	L1, L2, L3

	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.		
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	08	L1, L2, L3, L4

Course Outcomes:

The Student will be able to

1. Learn the history, background and development of Nanoscience and Technology
2. Understand the structure-property relationships in nanomaterials as well as the concepts, that are different from bulk counterpart.
3. Demonstrate a systematic knowledge of the range and breadth of application of nanomaterials.
4. Review critically the potential impact, in all classes of materials and nanostructure.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

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

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - I			
Course Title	**SYNTHESIS AND PROCESSING TECHNIQUES**	**Code**	**20INT14**
Teaching Hours/Week (L:P:SDA)	3:0:2	CIE Marks	40
Total Number of Lecture Hours	40	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Module	Content	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
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.	08	L1, L2, L3
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.	08	L1, L2, L3
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.	08	L1, L2, L3
4	**Biological methods:** Use of bacteria, fungi, Actinomycetes for nanoparticle	08	L1, L2, L3, L4

	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.		
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.	08	L1, L2, L3, L4

Course Outcomes:

Students will able to

1. Understand principles and mechanisms of various synthesis and processing techniques.
2. Demonstrate the knowledge to synthesize different nanomaterial choosing suitable method
3. Design desired nanostructure with size and morphology controlled to get desired property.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

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.

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - I			
Course Title	**CARBON BASED NANOSTRUCTURES**	**Code**	**20INT15**
Teaching Hours/Week (L:P:SDA)	3:0:2	CIE Marks	40
Total Number of Lecture Hours	40	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
1	**Carbon Nanotubes (CNT):** History, types of CNTs, synthesis methods, CVD method, Laser ablation and electric arc processes, growth mechanisms, purification and characterization methods, mechanical reinforcements, solid disordered carbon nanostructures.	08	L1, L2,
2	**Graphene**: Background, structure, exfoliation or synthesis methods- physical methods-micromechanical (scotch tape method), CVD, electric arc process. Chemical approaches- Hammers method, oxidation and reduction of graphite, solvothermal, supercritical fluid, solvent sonication method, chemically modified graphene, electrochemical synthesis and other methods.	08	L1, L2, L3,
3	**Fullerenes and derivatives**: Fullerenes and types, diamond like carbon, nanodiamond, clusters, metal carbide derived carbon nanostructures, synthesis and applications. **Nanostructures**: Graphite, Whiskers, Cones, and Polyhedral crystals, structure, properties and applications.	08	L1, L2, L3, L4
4	Functionalization of carbon nanostructures: (CNT, Graphene and fullerenes)- reactivity, covalent functionalization-oxidative purification, defect functionalization, transformation and modification of carboxylic functionalization like amidation, thiolation, halogenations, hydrogenation, addition of radicals, sidewall functionalization through electorphilic addition, nano covalent exohedralfunctionalization, endohedro functionalization.	08	L1, L2, L3, L4

5	**Properties of Carbon nanostructure:** Electronic, Vibrational, Mechanical Properties of CNTs, optical properties & Raman spectroscopy of CNTs. **Application of Carbon nanostructure** in Lithium ion battery, fuel cells, hydrogen storage, sensor applications, applications to nanoelectronics, nanocomposites, nanowires in drug delivery, polymer reinforcement and as filler materials.	08	L2, L3, L4

Course Outcomes:

After the successful completion of this course, the student will be able to:

1. Identify the type of carbon nanotubes and different synthesis methods and growth mechanisms.
2. Elucidate different properties and applications of carbon nanotubes in various fields.
3. Introduce the graphite derivatives, fullerenes and its type, nanodiamond, graphene, different synthesis methods.
4. Understand the importance offunctionalization of carbon nanostructures their application of carbon nanostructure for different day-to-day applications

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

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

Reference

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

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - I			
Course Title	**SYNTHESIS AND CHARACTERIZATION LAB**	**Code**	**20INTL16**
Teaching Hours/Week (L:P:SDA)	0:4:0	CIE Marks	40
Total Number of Lecture Hours	40	Exam Marks	60
Credits	02	Exam Hours	03

Course Learning Objectives:

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

1. Verification of Beer Lombard's Law
2. Synthesis of Au/Ag metal nanoparticles by Chemical reduction method, UV-Visible absorption studies of the Au/Ag metal nanoparticles
3. Synthesis of ZnO nanoparticles by hydrothermal method and Optical absorption spectra of the ZnO; Band gap estimation from the band edge
4. Synthesis of TiO_2 nanoparticles by Solvothermal method and Photocatalytic degradation property analysis
5. Synthesis of ceramic $BaTiO_3$ nanomaterial by combustion process and their crystal structure identification by X-ray diffraction studies
6. Synthesis of ceramic $SrTiO_3$ nanomaterial by Sol-Gel method and their Size Calculation Scherer's law by X-ray diffraction pattern
7. Surface functionalization or modification of Al_2O_3 metal oxide nanoparticles with organic reagents. Surface modification confirmation by dispersion in binary solvent (Organic-Aqueous) system.
8. Synthesis of 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. Surface functional group identification by FTIR measurement
10. Synthesis of ZnS/MoS nanoparticles by microwave Solvothermal method followed by size and morphology analysis

Course Outcomes:

The Student will be able

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

Question paper pattern:

- All laboratory experiments (nos) are to be included for practical examination.
- Students are allowed to pick one experiment from the above Listed experiments and execute.
- Strictly follow the instructions as printed on the cover page of answer script for breakup of marks. Change of experiment is allowed only once and marks allotted to the procedure part to be made zero.

TEXT BOOKS/REFERENCES:

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.

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - I			
Course Title	**RESEARCH METHODOLOGY AND IPR**	**Code**	**20INT17**
Teaching Hours/Week (L:P:SDA)	2:0:0	CIE Marks	40
Total Number of Lecture Hours	30	Exam Marks	60
Credits	02	Exam Hours	03

Course Learning Objectives:
Course objectives:

- To give an overview of the research methodology and explain the technique of defining a research problem
- To explain the functions of the literature review in research.
- To explain carrying out a literature search, its review, developing theoretical and conceptual frameworks and writing a review.
- To explain various research designs and their characteristics.
- To explain the details of sampling designs, and also different methods of data collections.
- To explain the art of interpretation and the art of writing research reports.
- To explain various forms of the intellectual property, its relevance and business impact in the changing global business environment.
- To discuss leading International Instruments concerning Intellectual Property Rights.

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
1	**Research Methodology:** Introduction, Meaning of Research, Objectives of Research, Motivation in Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Importance of Knowing How Research is Done, Research Process, Criteria of Good Research, and Problems Encountered by Researchers in India.	06	L1, L2
2	**Defining the Research Problem:** Research Problem, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem, An Illustration. **Reviewing the literature:** Place of the literature review in research, Bringing clarity and focus to your research problem, Improving research methodology, Broadening knowledge base in research area, Enabling contextual findings, How to review the literature, searching the existing literature, reviewing the selected literature,	06	L1, L2

	Developing a theoretical framework, Developing a conceptual framework, Writing about the literature reviewed.		
3	**Research Design:** Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Important Experimental Designs. **Design of Sample Surveys:** Introduction, Sample Design, Sampling and Non-Sampling Errors, Sample Survey versus Census Survey, Types of Sampling Designs.	06	L1, L2
4	**Data Collection**: Experimental and Surveys, Collection of Primary Data, Collection of Secondary Data, Selection of Appropriate Method for Data Collection, Case Study Method. **Interpretation and Report Writing:** Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports	06	L1, L2,L3,L4
5	**Intellectual Property:** The Concept, Intellectual Property System in India, Development of TRIPS Complied Regime in India, Patents Act, 1970, Trade Mark Act, 1999,The Designs Act, 2000, The Geographical Indications of Goods (Registration and Protection) Act1999, Copyright Act,1957,The Protection of Plant Varieties and Farmers' Rights Act, 2001,The Semi-Conductor Integrated Circuits Layout Design Act, 2000, Trade Secrets, Utility Models, IPR and Biodiversity, The Convention on Biological Diversity (CBD) 1992, Competing Rationales for Protection of IPRs, Leading International Instruments Concerning IPR, World Intellectual Property Organisation (WIPO),WIPO and WTO, Paris Convention for the Protection of Industrial Property, National Treatment, Right of Priority, Common Rules, Patents, Marks, Industrial Designs, Trade Names, Indications of Source, Unfair Competition, Patent Cooperation Treaty (PCT), Advantages of PCT Filing, Berne Convention for the Protection of Literary and Artistic Works, Basic Principles, Duration of Protection, Trade Related Aspects of Intellectual Property Rights(TRIPS) Agreement, Covered under TRIPS Agreement, Features of the Agreement, Protection of Intellectual Property under TRIPS, Copyright and Related Rights, Trademarks, Geographical indications, Industrial Designs, Patents, Patentable Subject Matter, Rights Conferred, Exceptions, Term of protection, Conditions on Patent Applicants, Process Patents, Other	06	L1, L2,L3,L4

	Use without Authorization of the Right Holder, Layout-Designs of Integrated Circuits, Protection of Undisclosed Information, Enforcement of Intellectual Property Rights, UNSECO.		

Course Outcomes:

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

- Discuss research methodology and the technique of defining a research problem
- Explain the functions of the literature review in research, carrying out a literature search, developing theoretical and conceptual frameworks and writing a review.
- Explain various research designs and their characteristics.
- Explain the art of interpretation and the art of writing research reports
- Discuss various forms of the intellectual property, its relevance and business impact in the changing global business environment and leading International Instruments concerning IPR

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

TEXT BOOKS:

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
3. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
4. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
5. Mayall, "Industrial Design", McGraw Hill, 1992.
6. Niebel, "Product Design", McGraw Hill, 1974.
7. Asimov, "Introduction to Design", Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
9. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Second Semester

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - II			
Course Title	**DESIGN AND FABRICATION TECHNIQUES**	**Code**	**20INT21**
Teaching Hours/Week (L:P:SDA)	3:0:2	CIE Marks	40
Total Number of Lecture Hours	40	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
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.	08	L1, L2, L3
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.	08	L1, L2, L3
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.	08	L1, L2, L3
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	08	L1, L2, L3, L4

	Decomposition, Thermomechanical Indentation, Mechanical Scratching, High Throughput Scanning Probe Lithography.		
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`	08	L1, L2, L3, L4

Course Outcomes:

Course Outcomes:

At the end of the course, students will be able to:

1. Understand and appreciate the importance of nanostructure and its impact device fabrication
2. Differentiate between nanofabrication process and understand the advantages and limitations of process for device fabrication
3. Understand the miniaturization of devices to Nano devices, process challenges and analyse theory for emerging Nano scale devices
4. Evaluate the advances in Nano scale technology and device fabrication their application in electronics, sensors, biomedical and energy generation and storage.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

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).

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - II			
Course Title	**CHARACTERISATION TECHNIQUES**	**Code**	**20INT22**
Teaching Hours/Week (L:P:SDA)	3:0:2	CIE Marks	40
Total Number of Lecture Hours	40	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
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.	10	L1, L2, L3
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.	10	L1, L2, L3
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	08	L1, L2, L3

	methods zeta potential.		
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.	07	L1, L2, L3, L4
5	**Electrical measurements** Cyclic Voltameter, Impedance Measurement, IV, AC and DC electric measurements, impedance spectral information.	05	L1, L2, L3, L4

Course Outcomes:

At the end of the course, students will be able to:

1. Identify the characterization technique suitable for their studies
2. Analyze the data from various characterization techniques used to evaluate nanomaterial structure, size, morphology and properties.
3. Understand the size and structure relationship and their suitability for an given engineering application.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

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

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 - 21) SEMESTER - II			
Course Title	**ADVANCED & SMART MATERIALS**	**Code**	**20INT23**
Teaching Hours/Week (L:P:SDA)	3:0:2	CIE Marks	40
Total Number of Lecture Hours	40	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
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.	08	L1, L2, L3
2	**Spintronic Materials:** Modelling the growth of Mn on semiconductor substrates, Dilute magnetic semiconductor nanocrystals, Advances in wide bandgap materials for semiconductor spintronics	08	L1, L2, L3
3	**Plasmonics:** Metallic Nanoparticles and Nanorods, Metallic Nanoshells. Local Field Enhancement, Subwavelength Aperture Plasmonics, Plasmonic Wave Guiding. Applications of Metallic Nanostructures. Radiative Decay Engineering.	08	L1, L2, L3
4	**Smart Materials and Systems** Thermoresponsive materials, piezoelectric materials, electrostrictive and magnetostrictive materials, 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.	08	L1, L2, L3, L4
5	**Advanced Materials in Catalysis:** Bimetallic Catalysts, Supported Bimetallic Catalysts, Graphite Intercalation Compounds as catalysts, Carbides, Nitrides, and	08	L1, L2, L3, L4

	Borides for Catalysis, Synthetic Layered Silicates and Aluminosilicates; Complex Catalysts on Inorganic Supports. **Advanced materials in Biomedical Application:** Zeolite Structures as Drug Delivery Systems, Mesoporous Silica Nanoparticles and Multifunctional Magnetic Nanoparticles in Biomedical Applications, Metal-Organic Frameworks for Biological and Medical Applications		

Course Outcomes:

At the end of the course, students will be able to:

1. Understand the crystal structure and characterization of various nanomaterials
2. Evaluate the characteristic crystal structure and their influence on properties of the materials.
3. Demonstrate their knowledge in advanced material science which helps in applications of various materials in engineering applications.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

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

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - I			
Course Title	**NANOTECHNOLOGY AND ENVIRONMENT**	**Code**	**20INT241**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Module	Content	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
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.	7	L1, L2, L3
2	**Nanostructure 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.	7	L1, L2, L3
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.	12	L2, L3, L4
4	**Nanotoxicology**	12	L1, L2, L3,

	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.		L4
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.	12	L1, L2, L3, L4

Course Outcomes:

After successfully completing this course, students will be able to

1. Apply nanomaterials in different environmental applications.
2. Demonstrate knowledge about the nanoparticles effect on health and safety issues.
3. Nanoparticles toxicity and their effect on health.
4. Understand Importance of clean rooms and their usage.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

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

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - II			
Course Title	**NANOCOMPOSITES AND APPLICATIONS**	**Code**	**20INT242**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
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.	10	L1, L2, L3
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.	08	L1, L2, L3
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	12	L1, L2, L3

	composites, elastomer and thermoplastic elastomer nanocomposites for propulsion systems, water borne fire-retardant nanocomposites, hybrid composites for cosmetics, protective and decorative coatings.		
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.	10	L1, L2, L3, L4
5	**Bio ceramics for implant coating** Calcium phosphates-hydroxyapatites Ti6Al4V 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.	10	L1, L2, L3, L4

Course Outcomes:

Students will be able to

1. Design different types nanostructures that are suitable to specific application.
2. Demonstrate a knowledge of polymer based nanocomposites and its applications.
3. Analyze the properties of polymer Nanocomposites and their behavior depending on the type of nanomaterials.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

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

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - II			
Course Title	**NANOBIOTECHNOLOGY**	**Code**	**20INT243**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Module	Content	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
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.	10	L1, L2, L3
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.	10	L1, L2, L3
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.	10	L1, L2, L3

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.	10	, L2, L3, L4
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.	10	L2, L3, L4

Course Outcomes:

The Student will be able to

1. Demonstrate knowledge of biotechnology to understand Nanobiotechnology.
2. Analyze the interaction of various biomolecules and nanostructures.
3. Design and develop nanostructures and biomolecules for various biological applications.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

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

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - II			
Course Title	**SURFACE ENGINEERING OF NANOMATERIALS**	**Code**	**20INT244**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

1. To impart knowledge on surface engineering of nanomaterials and their applications.
2. To Learn about different surface engineering coating technology.
3. To understand surface engineering with nanomaterials for different application

Module	Content	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
1	**Fundamentals**: Introduction to tribology, surface degradation, wear and corrosion, types of wear, adhesive, abrasive, oxidative, corrosive, erosive and fretting wear, classification of nano coatings, definition, scope and general principles, application of surface engineering towards nanomaterials.	10	
2	**Conventional surface engineering:** Surface engineering by material removal, material addition, surface modification using liquid/molten bath, thermal and chemical treatments, gaseous medium etc.	10	
3	**Advanced surface engineering practices:** Surface engineering by energy beams, laser assisted microstructural and compositional modification, electron and laser beam, ion beam, plasma beam etc.	10	
4	**Advanced coating practices:** Cold spray, sputter deposition, ion implantation, sol-gel technique, electrolysis and electroless techniques, HVOF, PVD, PECVD, CVD, ALD etc.	10	
5	**Functional coatings and Applications:** Brush, Screen printing, Spray, powder, Dip-coating, ED, Fluidized Bed, Electrostatic spray gun, photovoltaics, bio-and chemical sensors, semiconductors, polymers and composites, electronic, optical and magnetic devices, modeling.	10	

Course Outcomes:

The Student will be able to

1. Demonstrate knowledge of Nanomaterials potential in surface engineering application

2. Apply suitable nanomaterials as functional surface coating
3. Able to use the suitable surface coating technique to address engineering problems

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

TEXT BOOKS:

1. Morton, P.H., “Surface Engineering & Heat Treatment”, I.I.T, Brooke field. 1991
2. “ASM Metals Handbook: Surface Cleaning, Finishing & Coating”, Tenth Edition, Vol.5, Ohio, Metals Park, USA. 2000
3. Satas, D. and Tracton, A.A., “Coating technology handbook”, Mercel Dekker, New York. 2001

Reference Books

4 Davis, J.R., (Ed.)., “Surface Engineering for Corrosion and Wear Resistance”, ASM International, Materials Park, Ohio. 2001
5. Fontana, M.G., “Corrosion Engineering”, 3rd Edition, M. C. Graw Hill, New York. 2005
6. Winston Revie, R., (Ed.), “Uhlig's Corrosion Handbook”, 3rd Edition, John Wiley & Sons. New York. USA. 2011

Additional readings

7. Bieleman, J., “Additives for coating”, Wiley-VCH Verlag, Germany. 2008
8. Peter M. Martin, “Introduction to Surface Engineering and Functionally Engineered Materials”, Wiley. 2011
9 Pal, K., (Ed.), “Recent Advances in Elastomeric Nanocomposites”, Springer, Berlin 2011

M.Tech., Nanotechnology
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2020 -2021)
SEMESTER - II

Course Title	**NANOELECTRONICS**	**Code**	**20INT251**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives: 1. To understand the importance of nanoelectronics, technology roadmap in nanoelectronics and limitations of existing CMOS technologies for design of electronic circuits. 2. The course provides an insight on the advances in nanoelectronics devices such as High-K devices, FINFETs, CNTFETs, Molecular Electronics and Spintronics. 3. The course provides a strong theoretical and analytical understanding of nanoelectronic devices and its applications in design of electronic circuits.

Module	Content	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
1	**Introduction to Nanoelectronics** Technology roadmap of nano-electronics, Scaling of devices and technology jump, Challenge of the CMOS technologies, More-Moore and More-than-Moore. Review of semiconductor devices, Quantum statistical mechanics, Energy bands in silicon, **Metal Oxide Semiconductor Field Effect Transistors (MOSFET),** MOSFET Operation, Threshold Voltage and Subthreshold Slope, Current/voltage characteristics, Finite Element Modeling of MOS, CMOS technology, Challenges of the CMOS technologies, High-k dielectrics and Gate stack, Future interconnect.	10	L1, L2, L3
2	**Nanoscale MOSFETs** MOSFET as digital switch, Propagation delay, Dynamic and static power dissipation Moore's law, Transistor scaling, Constant field scaling theory, Constant Voltage Scaling, Generalized scaling, Short channel effects, Reverse short channel effect, Narrow width effect, Subthreshold conduction leakage, Subthreshold slope, Drain Induced Barrier Lowering, Gate Induced Drain Leakage, Design of NanoMOSFET, Halo implants, Retrograde channel profile, Shallow source/drain extensions, Twin well CMOS process flow, Gate Tunneling : Fowler Nordheim and Direct Tunneling, High k gate dielectrics, Metal gate transistor, Transport in Nanoscale MOSFET, Ballistic transport, Channel quantization.	10	L1, L2, L3
3	**Designing with FINFETs** Evolution of FinFET, Principle of FinFET, Finfet Technology, FinFET Schematic, Compact Drain-Current equation, Small Signal Model of Si- Based FinFET, FinFET Fabrication Flow, Power dissipation in FinFETs, Leakage power reduction techniques, Power gating, Dual sleep, Dual stack, Sleepy stack, Basic gate design using FinFET's, combinational logic, sequential logic, Adders, Multiplier, SRAM cell design	10	L1, L2, L3
4	**Designing with CNTFETs**	10	L1, L2, L3,

	Introduction to CNTs, CNT structure, metallic and semiconductor CNTs, energy bands in CNTs, types of CNTs: Single walled and multiwalled, physical, electrical and thermal properties of CNTs, fabrication of CNTs. CNTFETs, structure and model, small signal model, predictive technology models, N-Channel and P-Channel CNTFETs, model files of CNTFETs, basic gates using CNTFET, VI characteristics of CNTFET based inverter, designing of sub systems using CNTFETs, combinational and sequential circuits using CNTFETs, adders, multipliers and SRAM cell using CNTFETs.		L4
5	**Advances in Nanoelectronics** MOLECULAR NANOELECTRONICS: Electronic and optoelectronic properties of molecular materials, TFTs-OLEDs- OTFTs – logic switches, SPINTRONICS: Spin tunneling devices - Magnetic tunnel junctions- Tunneling spin polarization, -spin diodes - Magnetic tunnel transistor - Memory devices and sensors - ferroelectric random access memory- MRAMS	10	L1, L2, L3, L4

Course Outcomes:

At the end of the course, students will be able to:

1. Understand and appreciate the importance of nanoelectronics and its impact in next generation electronics and electronic products
2. Differentiate between MOS and emerging nanodevices technology, understand the advantages and limitations of MOS based circuits
3. Understand the technology migration from MOS to nano devices, process challenges and analyse the mathematical models for emerging Nanoscale devices
4. Design logic circuits, sub systems and complex digital circuits using FINFETs and CNTFETs
5. Evaluate the advances in Nanoscale technology development and understand the importance of emerging devices and technologies of molecular electronics and spintronics

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

TEXT BOOKS:

1. Yuan Taur and Tak H. Ning, Fundamentals of Modern VLSI Devices, Cambridge
2. Karl Goser, Peter Glosekotter, Jan Dienstuhl, ―Nanoelectronics and Nanosystems‖, Springer (2004)
3. Cyril Prasanna Raj P., Designing with FINFETs and CNTFETs, MSEC E-Publication (2016)
4. SadamichiMaekawa, ―Concepts in Spin Electronics‖, Oxford University Press (2006)

References:

1. V. Mitin, V. Kochelap, M. Stroscio, Introduction to Nanoelectronics, Cambridge University Press (2008)
2. Edward L. Wolf, ―Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience‖, Wiley-VCH (2006)
3. Streetman and Banerjee, Solid State Electronic Devices, Prentice-Hall

Rainer Waser, ―Nanoelectronics and Information Technology: Advanced Electronic

	Materials and Novel Devices, Wiley-VCH

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - II			
Course Title	**MEMS AND NEMS**	**Code**	**20INT252**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
1	**Introduction to MEMS** Historical background of Micro Electro Mechanical Systems, Feynman' s vision, Nano Technology and its Applications Multi-disciplinary aspects, Basic Technologies, Applications areas, Scaling Laws in miniaturization, scaling in geometry, electrostatics, electromagnetic, electricity and heat transfer.	10	L1, L2, L3
2	**Micro and Smart Devices and Systems: Principles** Transduction Principles in MEMS Sensors: Micro sensors-thermal radiation, mechanical and bio-sensors, Actuators: Different actuation mechanisms - silicon capacitive accelerometer, piezo-resistive pressure sensor, blood analyzer, conductometric gas sensor, silicon micro-mirror arrays, piezo-electric based inkjet print head, electrostatic comb-driver, Smart phone application, Smart buildings	10	L1, L2, L3
3	**Materials and Micro manufacturing** Semiconducting Materials., Silicon, Silicon dioxide, Silicon Nitride, Quartz, Poly Silicon, Polymers, Materials for wafer processing, Packaging Materials Silicon wafer processing, lithography, thin-film deposition, etching (wet and dry), wafer-bonding. Silicon micromachining: surface, bulk, LIGA process, Wafer bonding process.	10	L1, L2, L3
4	**Electrical and Electronics aspects** Electrostatics, Coupled Electro mechanics, stability and Pull-in phenomenon, Practical signal conditioning Circuits for Microsystems. Characterization of pressure sensors, RF MEMS. Switches varactors, tuned filters. Micromirror array for control and switching in optical communication,	10	L1, L2, L3, L4

	Application circuits based on microcontrollers for pressure sensor, Accelerometer, Modeling using CAD Tools (Intellisuite)		
5	**Integration and Packaging of Microelectromechanical Systems** Integration of microelectronics and micro devices at wafer and chip levels. Microelectronic packaging: wire and ball bonding, flip-chip. Microsystem packaging examples, Testing of Micro sensors, Qualification of Mems devices	10	L1, L2, L3, L4

Course Outcomes:

At the end of the course, students will be able to:

1. Demonstrate the knowledge of the basics and develop applications for microsystems
2. Operations of MEMS transducers
3. Applications of electrostatics in MEMS sensors and actuators

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

TEXT BOOKS:

1. G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, V. K. Aatre, “Micro and Smart Systems”, Wiley India, 2010.
2. T R Hsu, “MEMS and Microsystems Design and Manufacturing”, Tata McGraw Hill, 2nd Edition, 2008

References:

1. Chang Liu, “Foundations of MEMS”, Pearson International Edition, 2006.
2. S. D. Senturia, “Micro System Design”, Springer International Edition, 2001.

M.Tech., Nanotechnology
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2020 -2021)
SEMESTER - II

Course Title	**INDUSTRIAL APPLICATIONS OF NANOTECHNOLOGY**	**Code**	**20INT253**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objective:

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

Modules	**Contents**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
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	10	L1, L2, L3
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.	10	L1, L2, L3
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	08	L1, L2, L3

	Nanoreactors - Organic electroluminescent displays		
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	10	L1, L2, L3, L4
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.	12	L1, L2, L3, L4

Course Outcomes:

The Student will be able to

1. Demonstrate the knowledge of various industrial applications of nanotechnology.
2. Will be able predict future technological advancements and increasing role of nanotechnology in each industry

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

TEXT BOOKS:

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).

M.Tech., Nanotechnology **[As per Choice Based Credit System (CBCS) scheme]** **(Effective from the academic year 2020 -2021)** **SEMESTER - II**			
Course Title	**NANOTECHNOLOGY IN CIVIL ENGINEERING**	**Code**	**20INT254**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objective:

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

Modules	**Contents**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
1	**Nanomaterials as Construction Materials :** History of Cementitious Systems, Current Trends in Nano-modification of Cementitious Systems, **Nano-seeding and Crystallization Control:** The Hardening of Construction Materials: Hydration in Ordinary Portland Cement, Correlation between Hydrates, Microstructure and Cohesion Properties in Cement, Gypsum Hydration, Hydration of Plaster. Experimental Techniques to Characterize the Microstructure Development. Nano-engineering of Nucleation: Design of C-S-H Nucleation and Growth. Nano-modification of Crystal Growth: Nano-modification of Gypsum Growth, From Hydration to Crystallization, From Microscopic to Macroscopic	10	L1, L2, L3
2	Nanomaterials in Cement- **The Effect of Nanomaterials on Cement Hydration and Reinforcement:** Effects of Nanomaterials and SWCNT on the Hydration of Sonicated OPC, Dispersion of SWCNT for Use in Cementitious Composites, Effects of SWCNT and Other Nanomaterials on the Hydration of C_3S and OPC, Reinforcing Behavior in SWCNT Composites	10	L1, L2, L3

3	**Multifunctional and Smart Carbon Nanotube Reinforced Cement-Based Materials:** Current Approaches for Dispersing CNTs in Cement-Based Materials, Reinforcement Mechanisms, Mechanical Properties of CNTs, Mechanical Properties of Nanocomposites, Electrical, Piezoresistive Thermal Conductive and Damping Properties Properties of CNTs Reinforced Cement-Based Materials, Potential Structural Applications of CNTs Reinforced Cement-Based Materials, Challenges for Development and Deployment of Multifunctional and Smart CNTs Reinforced Cement-Based Materials	10	L1, L2, L3
4	**Nanomaterials-Enabled Multifunctional Concrete and Structures:** Self-sensing Nano-concret and Structure, Piezoresistivity of Nano-concrete and the Modeling, Effect of Water Content on Electrical Property of CBCC and the Water-Proofing Method, Self-sensing Concrete Structures, Mechanical Properties of Nano-concret, Microstructure, Strength, Abrasion Resistance of Concrete Containing Nano-particles, Flexural Fatigue Performance of Concrete Containing Nano-particles for Pavement, Future of Multifunctional Nano-concrete	10	L1, L2, L3, L4
5	**Next-Generation Nano-based Concrete Construction Products: A Review:** Incorporation of Nano-scale and Nanostructured Materials: Incorporation of Nano-SiO, during Mixing, Incorporation of Nano-TiO2, Incorporation of Nano-Al2O3, Incorporation of Nano-ZrO2, Calcium Carbonate Nano Particle Addition, Early Age Strength Increase of Belite Cement, Reinforcements of Nanotubes/Nanofibers, Nano Clay Composite. Self-healing Polymer to Control Microcracking, Self-sensing of Concrete Stress, Self Consolidating Concrete (SCC), Reactive Powder Concrete (RPC), Nanoporous Thin Film Technology to Improve Concrete Performance, Nano-engineering of Concrete Pore Solution, Controlled Release of Admixtures, Nanotechnology in Building, Nanotechnology Based Devices	10	L1, L2, L3, L4

Course Outcomes:

The Student will be able to understand

1. Application of Nanomaterials in construction
2. Effect of Nanomaterialsstrength, stability and resistance to chemical, Biological and Mechanical attack
3. How Nanomaterials improves quality of construction

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

TEXT BOOKS:

1. Nanotechnology in Civil Infrastructure A Paradigm Shift, Editors: Gopalakrishnan, K., Birgisson, B., Taylor, P., Attoh-Okine, N.O. (Eds.) 2011Publisher Springer International Publishing
2. Nanotechnology in Construction, Proceedings of NICOM5, Editors: Sobolev, Konstantin, Shah, Surendra P. (Eds.) 2015, Publisher Springer International Publishing
3. Nanotechnology in Eco-efficient Construction, Materials, Processes and Applications, Editors: Fernando Pacheco-Torgal Maria Vittoria Diamanti Ali Nazari Claes Goran-Granqvist Alina Pruna Serji Amirkhanian, 2018, Imprint: Woodhead Publishing, ISBN: 9780081026410, eBook ISBN: 9780081026427

References:

1. Advanced Research on Nanotechnology for Civil Engineering Applications (Advances in Civil and Industrial Engineering), by Anwar Khitab (Editor), Waqas Anwar (Editor)Hardcover – 30 June 2016
2. Smart Buildings: Advanced Materials and Nanotechnology (Kindle Edition)by Casini, Marco, ISBN: 0081009720, Publisher: Woodhead Publishing; 1 edition, 2016
3. Nanomaterials in Structural Engineering, By Małgorzata Krystek and Marcin Górski 2018DOI: 10.5772/intechopen.79995

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - II			
Course Title	**DEVICE FABRICATION AND CHARACTERIZATION LAB**	**Code**	**20INTL26**
Teaching Hours/Week (L:P:SDA)	0:4:0	CIE Marks	40
Total Number of Lecture Hours	40	Exam Marks	60
Credits	02	Exam Hours	03

Course Learning Objectives:

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

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
9. Fabrication of electrode for electrochemical oxidation of organic molecules.
10. Battery device Fabrication and its performance data analysis.

Course Outcomes:

1. Design the nanomaterial for suitable application
2. Basic hands on experience to fabricate selected nanomaterials based devices
3. Knowledge to operate the device and measure data.

Question paper pattern:

- All laboratory experiments (nos) are to be included for practical examination.
- Students are allowed to pick one experiment from the above Listed experiments and execute.
- Strictly follow the instructions as printed on the cover page of answer script for breakup of marks. Change of experiment is allowed only once and marks allotted to the procedure part to be made zero.

TEXT BOOKS:

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

Roland Wiesendanger

References:

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

Third

Semester

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - III			
Course Title	**NANOMATERIALS AND ENERGY SYSTEMS**	**Code**	**20INT31**
Teaching Hours/Week (L:P:SDA)	3:0:2	CIE Marks	40
Total Number of Lecture Hours	40	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

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

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
1	Renewable energy Technology: Energy challenges, nanomaterials and nanostructures in energy harvesting, developments and implementation of nanotechnology based renewable energy technologies, solar cell structures: quantum well and quantum dot solar cells, photo-thermal cells for solar energy harvesting, thin film solar cells, CIGS solar cells, Dye sensitized solar cells. Organic PV cells, Concentrated solar power (CSP): Reflective materials, absorptive coatings, thermal storage.	08	1, 2, 3
2	**Energy storage:** Introduction, Battery types, Li-ion Battery, Battery components materials, cathodes, anodes, effect of nanosize on energy storage and electrode materials performance. Next generation batteries, Li-Air, Li-S, Na ion battery, Mg ion battery. LIB for automobiles application, EV's, HEV, PHEV and power grid.	08	2, 3, 4
3	**Super capacitors:** Introduction, Electrochemical energy storage, Electrochemical capacitors, Electrochemical double layer capacitor, electrode materials supercapacitors, Hybrid Nanostructures for supercapacitors- metal oxides, conducting polymers, Electrolytes for super capacitors, types of electrolytes.	08	1, 2, 3
4	**Hydrogen Generation and storage technology:** Hydrogen production methods, Electrochemical and photocatalytic H2 Generation using Nanomaterials, purification, hydrogen storage methods and materials:	08	2, 3

	metal hydrides and metal organic framework materials, volumetric and gravimetric storage capacities, hydriding and dehydriding kinetics, high enthalphy formations and thermal management during hydriding reaction, multiple catalytic- degradation of sorption properties, automotive applications. Catalyst of hydrogen production, steam reforming & Water splitting. Nanoporous membranes for hydrogen separation.		
5	**Fuel cell technology:** Fuel cell principles, types of fuel cells (Alkaline Electrolytie, phosphoric acid, Molten carbonate, solid oxide and direct methanol and proton exchange fuel cells), Principle and operation of proton exchange membrane (PEM) fuel cell, materials and fabrication methods for fuel cell technology, micro fuel cell power sources-biofuels.	08	1, 2, 3, 4

Course Outcomes:

Students will be able to demonstrate

1. Better understanding of Renewable energy, importance.
2. Application of nanotechnology in different energy generation and storage technology.
3. Importance of nanosize and nanostructure in improving energy storage and generation efficiency of the systems.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

Text Book

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

Reference

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

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - III			
Course Title	MODELING AND SIMULATION IN NANOTECHNOLOGY	**Code**	**20INT321**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

1. Learn about basic principles computing and modeling.
2. Apply quantum mechanical methods.
3. To learn the modeling of nanoparticles
4. Modeling, design and simulation of NEMS and MEMS

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
1	Quantum mechanics of atoms and molecules: Hamiltonian and Wave functions-orbital approximation for multi-electron atoms-Pauli's Anti-symmetry principle, Born-Oppenheimer approximation, MO theory, LCAO approximation. Approximation methods: Necessity of approximate methods, the variation method, Perturbation method.	10	L1, L2, L3
2	Quantum Mechanical methods - Hartree Fock, Density Functional Theory, Configuration Interaction, Tight Binding, MNDO. Force Fields methods - Energy terms: valence, van der Waals, Coulomb. Functional forms, Dreiding, UFF. Charge transfer QEq, NB Cutoffs, Splines. Minimization: steepest descent, conjugate gradients, FP.	10	L1, L2, L3
3	Molecular Dynamics simulations - NVE ensemble: Newton;s Equations, Verlet algorithms, time step. Velocity initialization (Boltzmann), Equilibration, Anneal, Quench. Analysis: fluctuations, Kubo, Free Energy Pert Theory. NVT ensemble, NPT ensemble, Quantum Hopping MD. Monte Carlo methods –Introduction, Integration, Simulation, Random Walk, Percolation, Ising Model, Markov, Metropolis, RIS, CCBB. Solvation Methods - PB, QM, MD, MC; SGB,	10	L1, L2, L3

	AVGB.		
4	Computational Modelling of Nanoparticles: Introduction, Benefits of Computer Science for nanotechnology, modelling at different scales – electronic, atomistic, meso and continuum. Concept of computational modelling of nanostructures, computational control of matter through modelling – empirical and Abinitio potentials, molecular dynamics simulation, monte carlo simulation, advantages and limitations of MDS and MCS. Modeling of nanoparticles - electronic transport, mechanical properties, optical properties. Bionanoparticles and polymer nanocomposites. Opportunities and challenges in computer modelling of nanoparticles.	10	L1, L2, L3, L4
5	Modeling, design and simulation of NEMS and MEMS: Introduction, Lumped Modeling of carbon nanotubes, design and simulation of carbon nanotubes–sugar design, sugar cube design and simulation and applications. Lumped modeling of MEMS-sugar to sugarcube, Librarian, parameterization, simulation, static analysis, steady state analysis, sinusoidal analysis, transient analysis and optimization. Design and simulation of NEMS and MEMS: Sugar model, sugar cube model, carbon nanotube model in sugar, first-order analysis of thermal actuator, thermo-mechanical response of the device, electro-thermo-actuator model.	10	L1, L2, L3, L4

Course Outcomes:

The Student will be able to

1. Demonstrate the physical basis for quantum mechanics for nanotechnology
2. Quantum mechanical treatment for atomic and molecular aspects.
3. Simulation and modeling of various nanostructures and their properties
4. Design and modeling of NEMS and MEMS devices

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

Text Book

1. Jerrod H.Zar (1999) Biostatistical analysis by Prentice hall international Inc Press, London
2. “Handbook of theoretical and computational Nanotechnology” eds. Michael Rieth and wolfram schommers, 2006.
3. Computational physics, R. C. Verma, K. C. Sharma & P. K. Ahluwalia.

Reference

1. Computational Nanotechnology: Modeling and Applications with MATLAB® edited by Sarhan M. Musa
2. Computational Finite Element Methods in Nanotechnology edited by Sarhan M. Musa

M.Tech., Nanotechnology
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2020 -2021)
SEMESTER - III

Course Title	**NANOTECHNOLOGY AND DRUG DELIVERY**	**Code**	**20INT322**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

1. Students will learn underlying principles of drug delivery systems.
2. Understand the application of nanostructures as drug delivery systems.
3. Nanoparticles based drug formulation for cancer therapy and bio imaging application.

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
1	**Principles of drug delivery systems (DDS)** Design of drug delivery systems, Aims of DDS, Modes of drug delivery, ADME hypothesis – controlled drug delivery, site specific drugs , barriers for drug targeting, passive and active targeting, Strategies for site specific, time and rate controlled delivery of drugs, antibody based and metabolism-based targeting.	10	L1, L2, L3
2	**Nano sized Drug Carriers** Structure and Preparation- Liposomes, Cubosomes and Hexosomes, Solid Lipid Nanoparticles (SLP). Lipid based colloidal system, Liposomal Drug Carriers, Dendrimer (PAMAM), Polymer Micelle, Ceramic and Magnetic nanoparticle, Polymer drug conjugates. Nanotubes, Nanowires, Nanocage, Nanorods, Nanofibers, and Fullerenes, Carbon nanotubes biocompatibility. Smart drug delivery systems, Multifunctional Drug carriers, organic and inorganic	10	L1, L2, L3

	composites. Problems with DDS, Drug loading efficiency in nanovehicles, complexity of Nanocarriers, interface between synthetic materials and biological tissues or components, safety and ethical issues, Nanotechnology for future DDS.		
3	**Drug Discovery & Cancer therapy** Drug Discovery Using Nanocrystals, Drug Discovery Using Resonance Light Scattering (RLS) Technology. Nanosensors in Drug Discovery, Drug Delivery Applications, Nanorobots, Benefits of Nano-Drug Delivery. Use of microneedles and nanoparticles for local highly controlled drug delivery. Metal nanoparticles in drugs discovery. Nanotechnology for Cancer therapy-Nanobodies, Nanoparticles, nanoshells, Nanobombs, pebbles for brain tumor therapy, Targeting through angiogenesis and Folate Receptors Liposomal formulation in cancer therapy, application of liposomes in pharmaceutical and cosmetic applications.	10	L1, L2, L3
4	**Nanomedicines** Introduction, Applications of nanobiotechnology in medicine, Role of nanotechnology in methods of treatment, Nanomedicines for Nervous system, Developing Nanomedicines, Protocols for nanodrug Administration, Nanotechnology in Diagnostics applications, materials used in Diagnostics and Therapeutic applications - Molecular Nanomechanics, Molecular devices, Nanomedicines for Skin disorders, wound healing, eye diseases, infections, Nanotubes for detection and destruction of bacteria.	10	L1, L2, L3, L4
5	**Nanoanalytics** Nanoparticles for biological labelling, Nano-Imaging Agents, Nano particles molecular labels, Immunogold-silver staining, combined fluorescent and gold probes, Protein Labeling, gold cluster labelled peptides, gold cluster conjugates of other small molecules, gold-lipids metallosomes, Larger covalent particles labels, gold targeted to His Tabs, gold cluster nanoscrystals.	10	L1, L2, L3, L4

Course Outcomes:

Course Outcomes:

At the end of the course, students will be able to:

1. Demonstrate the knowledge to develop nanoparticle based new types of biomedical markers and therapeutic agents.
2. Evaluate the suitable nanostructure for drug delivery systems application.
3. Develop nanoparticles based drug formulation for cancer therap

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

TEXT BOOKS:

1. Nanotechnology in Drug Delivery: Melgardt M. de Villiers, PornanongAramwit, glen s. Kwon, Springer, 2009

2. NanoBiotechnology: BionInspired Devices and Materials for the Future: OdedShoweyov, Ilan Levy, Humana Press, New Jersey 2010
3. Nanobiotechnology, Concepts applications and Perspectives: C. M. Niemeyer and Chad A. Mirkin, Wiley VCH, 2009

References:

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

M.Tech., Nanotechnology
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2020 -2021)
SEMESTER - III

Course Title	**MICRO AND NANO FLUIDICS**	**Code**	**20INT323**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

1. A comprehensive understanding of micro and nanofluidics.
2. Learn about Fabrication techniques of Nanofluidic channels, Lab-on-chip concept and application.
3. Understanding the behavior of Biomolecule's in microfluidic channels.

Module	**Content**	**Teach-ing Hours**	**Revised Bloom's Taxonomy (RBT) Level**
1	**Introduction** Fundamentals of kinetic theory-molecular models, micro and macroscopic properties, binary collisions, distribution functions, Boltzmann equation and Maxwellian distribution functions-Wall slip effects and accommodation coefficients, flow and heat transfer analysis of microscale Couette flows, Pressure driven gas micro-flows with wall slip effects, heat transfer in micro-Poiseuille flows, effects of compressibility. **Pressure Driven Liquid Microflow:** Apparent slip effects, physics of near-wall microscale liquid flows, capillary flows, electro-kinetically driven liquid micro - flows and electric double layer (EDL) effects, concepts of electroosmosis, electrophoresis and dielectro-phoresis.	10	L1, L2, L3

2	**Laminar flow** Hagen-Poiseullieeqn, basic fluid ideas, Special considerations of flow in small channels, mixing, microvalves&micropumps, Approaches toward combining living cells, microfluidics and 'the body' on a chip, Chemotaxis, cell motility. Case Studies in Microfluidic Devices. **Ionic transport:** Polymer transport – microtubule transport in nanotuble channels driven by Electric Fields and by Kinesin Biomolecular Motors - Electrophoresis of individual nanotubules in microfluidic channels.	10	L1, L2, L3
3	**Fabrication techniques for Nanofluidic channels –** Biomolecules separation using Nanochannels - Biomolecules Concentration using Nanochannels – Confinement of Biomolecules using Nanochannels. **Hydrodynamics:** Particle moving in flow fields – Potential Functions in Low Renoylds Number Flow – Arrays of Obstacles and how particles Move in them: Puzzles and Paradoxes in Low Re Flow**.**	10	L1, L2, L3, L4
4	**Microfluidics and Lab-on-a-chip** Microfluidic Devices - Microchannels, Microfilters, Microvalves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Concepts and Advantages of Microfluidic Devices - Fluidic Transport - Stacking and Scaling – Materials for The Manufacture (Silicon, Glass, Polymers) - Fluidic Structures - Fabrication Methods - Surface Modifications - Spotting - Detection Mechanisms. Microcontact printing of Proteins-Strategies- printing types-methods and characterization- Cell nanostructure interactions-networks for neuronal cells. Applications in Automatic DNA sequencing, DNA and Protein microarrays.	10	L1, L2, L3, L4
5	**BioMEMS** Introduction and Overview, Bio-signal Transduction Mechanisms: Electromagnetic Transducers Mechanical Transducers, Chemical Transducers, Optical Transducers – Sensing and Actuating mechanisms (for all types). Case Studies in Biomagnetic Sensors, Applications of optical and chemical transducers. Ultimate Limits of Fabrication and Measurement, Recent Developments in BioMEMS and BioNEMS - An alternative approach to traditional surgery, Specific targeting of tumors and other organs for drug delivery, Micro-visualization and manipulation, Implantation of microsensors, microactuators and other components of a larger implanted device or external system (synthetic organs).	10	L1, L2, L3, L4

Course Outcomes:

The Student will be able to

1. Demonstrate knowledge about Pressure driven liquid microflow, laminar flow, ionic transport, fabrication techniques for nano fluidic channels.
2. Analyze the biomolecule behavior in microfluidic channels.

3. Design the lab on chip devices and BiMEMS devices and their applications.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

TEXT BOOKS:

1. Joshua Edel “Nanofluidics” RCS publishing, 2009.
2. PatricTabeling “Introduction to Microfluids” Oxford U. Press, New York 2005.
3. K. Sarit “Nano Fluids; Science and Technology”, RCS Publishing, 2007.

References:

1. M. Madou, Fundamentals of Microfabrication, CRC Press, 1997
2. G. Kovacs, Micromachined Transducers, McGraw-Hill, 1998
3. Steven S Saliterman, Fundamentals of BioMEMS and Medical Microdevices, 2006

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - III			
Course Title	**NANOTECHNOLOGY FOR CORROSION SCIENCE AND ENGINEERING**	**Code**	**20INT324**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

1. A comprehensive understanding of corrosion science.
2. Learn about Nanomaterials based coating used to prevent corrosion .

Module	Content	Teach-ing Hours	Revised Bloom's Taxonomy (RBT) Level
1	**Introduction to corrosion science and engineering**. Drawbacks of using hexavalent chromium coatings, nanocrystalline coatings, nano Cobalt-phosphorous, nanostructured diamond, hydroxyapatite and metalloceramics coatings, Corrosion behaviour of nc-alloys.	10	L1, L2, L3
2	**Ceramic coatings:** Corrosion resistance Properties of ceramic nanoparticles, hard and soft coatings, SiC, ZrO2, and A12O3 coatings. application of nano ceramic particles incorporated paints in automobile industry.	10	L1, L2, L3
3	**Polymers:** Introduction to nanostructured conducting polymers and their composites. Applications of polyaniline, polypyrrole, polythiophene nanocomposites in corrosion control.	10	L1, L2, L3, L4
4	**Self-assembled nanophase coating:** self-assembled nanophase particle (SNAP) surface treatment. Incorporation of nanoparticles in the hybrid sol–gel systems, inhibitor nanoreservoirs for prolonged (controlled) release.	10	L1, L2, L3, L4
5	Self-cleaning paints and biocidal coatings, super hydrophobicity, concept of contact angle, nano TiO2 based paints (photo catalysis)	10	L1, L2, L3, L4

Course Outcomes:

The Student will be able to

1. Analyze the suitability of the material to be used to prevent corrosion
2. Develop a suitable coating for corrosion inhibition

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.

- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.
- The total marks will be proportionally reduced to 60 marks as SEE marks is 60.

TEXT BOOKS:

References:

1) Corrosion Protection and Control Using Nanomaterials
A volume in Woodhead Publishing Series in Metals and Surface Engineering, Book • 2012, Edited by: Viswanathan S. Saji and Ronald Cook

2) V. S. Saji* and Joice Thomas, Nano-materials for corrosion control,REVIEW ARTICLE CURRENT SCIENCE, VOL. 92, NO. 1, 10 JANUARY 2007

M.Tech., Nanotechnology
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2020 -2021)
SEMESTER - III

Course Title	**NANOBIOELECTRONICS AND APPLICATIONS**	**Code**	**20INT331**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:
1. To understand DNA and other biosystems and their structure.
2. To introduce concept of Microfluidic devices and their application.
3. To learn applications of different nanostructures and biomaterials in developing nanobioelectronic devices and as molecular labelling.

Module	Content	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
1	**Bionanoelectronics** Introduction,Photoinduced Electron transport in DNA: Toward Electronic Devices Based on DNA Architecture, Effective Models for charge Transport in DNA Nanowires, Optimizing Photoactive Proteins for Optoelectronic, DNA Based Nanoelectronics, Electrical Manipulation of DNA on Metal Surfaces.	10	L1, L2, L3
2	**Microfluidics Meets Nano:** Introduction, Overview, Definition and History, Advantages of Microfluidic Devices, Concepts for Microfluidic Devices, Fluid Transport, Stacking and Sealing, Methods, Materials for the Manufacture of Microfluidic Components, Silicon, Glass, Polymers, Fluidic Structures, Fabrication Methods, Surface Modifications, Spotting, Detection Mechanisms.	10	L1, L2, L3
3	**Nanoparticle-Biomaterial hybrid systems for Bioelectronic Devices and Circuitry** Introduction, Biomaterial- Nanoparticles Systems for Bio-electtronic and Biosensing Applications, Bioelectronic systems based on nanoparticle-Enzyme Hybrids, Bioelectronic Systems for sensing of biorecognition events on Nanoparticles, Biomaterial based Nanocircuitry, Protein based Nanocircuitry, DNA as Functional Template for Nanocircuitry.	10	L1, L2, L3
4	**DNA based Nanostructures** Overview, Introduction, Oligonucleotide-Enzyme Conjugates, DNA Conjugates of binding proteins, Noncovalent DNA Streptavidin Conjugates, Multifunctional Protein Assemblies, DNA Protein Conjugates in Microarray Technologies, Methods, Conjugation of Nucleic Acids and Protein, Immuno PCR,	10	L1, L2, L3, L4

	Supramolecular Assembly, DNA directed Immobilization, DNA templated Electronics, Sequence Specific Molecular Lithography.		
5	**Nanoparticle Molecular labels** Introduction, Immunogold Silver staining, Combined Fluroscent and Gold probes, Methodology, Choice of Gold and AMG Type , Iodization, Sensitivity, Applications for the microscopical detection of Nucleic acids, guidelines and laboratary protocols, Gold derivatives of other biomolecules, protein labeling, gold Cluster of conjugates of other small molecules, gold lipids: metallasomes, Larger Covalent particle labels, Gold Targeted to His Tags, Enzymes Metallography, Gold Cluster Nanocrystals, Gold Cluster Oligonucleotide Conjugate: Nanotechnology applications, DNA Nanowires, 3-D Nanostructured Mineralized Biomaterials, Gold Quenched molecular beacons, Other Metal Cluster Labels, Platinum and Palladium, Tungstates, Iridium.	10	L1, L2, L3, L4

Course Outcomes:

After successfully completing this course, students will be able to

1. Apply DNA and its application bioelectronics devices.
2. Demonstrate knowledge about the Biomolecules and nanostructure interaction.
3. Understand Nanoparticles application in biomedical application.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. **"Nanobiotechnology"**. Edited by **C Niemeyer, Chad Mirkin,** WILEY-VCH , ISBN 3-527-30658-7.
2. "Nanobiotechnology". Edited by OdedShoseyov, Ilan Levy, Humana Press Inc., ISBN 978-61737-830-0.

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - III			
Course Title	**MICRO-NANO PACKAGING**	**Code**	**20INT332**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

1. Present building block technologies to package micro and nano-electronics, photonics, MEMS, and RF/wireless product
2. Describe the role of Packaging as IC and Device Packaging
3. Design and fabricate systems packaging to go from wafer to complete system
4. Demonstrate the role of test, inspection and reliability of electrical, mechanical and materials in micro and nano-electronics and devices packaging.

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
1	**Fundamentals of the Design and Packaging Process** - Systems Engineering, Quality Concepts, Engineering Documentation, Design for Manufacturability, ISO9000, Bids and Specifications, Reference and Standards Organizations. Introduction to Micro and nano systems packaging, role of packaging as IC and device packaging, fundamentals of electrical package design, Single Chip, Multi-chip, IC assembly, and Wafer Level Packaging.	10	L1, L2, L3
2	**Surface Mount Technology** - Introduction, Surface Mount Device Definitions, Substrate Design Guidelines, Thermal Design Considerations, Adhesives, Solder Joint Formation, Parts, Reflow Soldering, Cleaning and Prototype Systems. Direct Chip Attach - Overview of Die Assemblies, Known Good Die, Chip on Board, Flip Chips, and Chip-Scale Packages	10	L1, L2, L3
3	**Circuit Boards**- Overview, Basic Circuit Board Design, Prototypes, DFM and DFT Issues, Board Materials, Circuit Design and Board Layout, Simulation, Standards. Hybrid Assemblies: Introduction, Ceramic Substrates, Thick Film, Thin Film, Chip Resistors and Multilayer Ceramic Capacitors, Component and Assembly Packages, Buried Passive Circuit Elements, Bare Die Assembly, Multichip Module Technology.	10	L1, L2, L3, L4
4	**Interconnects** - General Considerations, Wires for	10	L1, L2, L3,

	Interconnection, Single-Point Interconnects, Connectors, Board Interconnects, Component Sockets, Fiber-Optic Interconnects and Connections, Coaxial Cable and Interconnects, Microwave Guides and Couplers. **Thermal Management:** Fundamentals of Heat, Engineering Data, Heat Transfer, Heat Removal/Cooling. **Testing**: Testing Philosophies, Test Strategies, Sources of Faults, Automatic Test Methods, Test Fixtures, Environmental Stress Screening, Test Software, and Testing Software Programs.		L4
5	**Inspection** - General Inspection Criteria, Solder Paste Deposition Volume, Solder Joint Inspection Criteria, Visual Inspection, Automated Optical Inspection, Laser Inspection, X-Ray Inspection. Package/Enclosure: Introduction, Ergonomic Considerations, User Interfaces, Environmental Issues, Maintenance, Safety. **Electronics Package Reliability and Failure Analysis**: Reliability, Micro-mechanisms of Failure in Electronic, Packaging Materials, Package Components, Failure Analyses of Electronic Packages, Thermal Management, Product Safety and Third-Party Certification.	10	L1, L2, L3, L4

Course Outcomes:

At the end of the course, students will be able to:

1. Demonstrate packaging of micro and nano electronic based devices and system for cutting edge electronic system.
2. Test, inspect, and failure analysis of micro and nano-scale packaged product.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. The electronic packaging handbook edited by Glenn R. Blackwell, CRC Press LLC, 2000.
2. Fundamentals of microsystem packaging by Rao R. Tummala, McGraw-Hill, 2004

Reference Books:

1. Micro- and Opto-Electronic Materials and Structures: Physics, Mechanics, Design, Reliability, Packaging by E. Suhir, Y.C. Lee, and C.P. Wong, Springer Science, 2007.
2. Nanopackaging: Nanotechnologies and Electronics Packaging by James E. Morris, Springer Science, 2008.

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - III			
Course Title	**ADVANCES IN NANODEVICES**	**Code**	**20INT333**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

1. To understand CMOS technology, scaling issues and analyze the need for nano-CMOS devices
2. To study the fabrication process and applications of nano capacitors, Nanoantennas, memristors, and nanomemory
3. To study fabrication process of CNTs, Nanowires and Quantum dots and understand the technologies behind use of these devices for medical and environmental applications

Module	Content	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
1	**Nanoelectronic Devices** Nano-CMOS modelling, Nano-CMOS Predictive Technology Model, Mobility and Dopant Number Fluctuation Model, Random interface traps, Nano-CMOS Technology, Bottom-Up approach for CMOS scaling, Low power adders.	10	L1, L2, L3
2	**Nano Capacitors and Terahertz systems** Package-compatible high density nanoscale capacitors, Carbon nanostructures for display and energy, Nano antennas for energy conversion, Ballistic transistor logic for circuit applications.	10	L1, L2, L3
3	**Memristors, Resistive switches and memory** Nanodevices: functions and Lienard equation, Sensing and writing operations of nanocross bar memory arrays, Complementary resistive switches, Memory cell using memristor, Thermally actuated nanoelectromechanical memory.	10	L1, L2, L3, L4
4	**CNT and Nanowire** Fabrication of single walled CNT, CNT for TFT, Yield improvement techniques for CNTFET, GaAs nanowires on Si Substrates, Tin Oxide Nanowires for Gas sensing, Cu Silicide Nanowires for Li-Ion Batteries, Zinc Oxide Nanowires for bio sensing, ZnO thin film transistors.	10	L1, L2, L3, L4
5	**Microfluidics and Lab-on-a-chip:** Microfluidic Devices - Microchannels, Microfilters, Microvalves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Concepts and Advantages of Microfluidic Devices - Fluidic	10	L1, L2, L3, L4

	Transport - Stacking and Scaling – Materials for The Manufacture (Silicon, Glass, Polymers) - Fluidic Structures - Fabrication Methods - Surface Modifications - Spotting - Detection Mechanisms. Micro contact printing of Proteins-Strategies- printing types- methods and characterization-Cell nanostructure interactions-networks for neuronal cells. Applications in Automatic DNA sequencing, DNA and Protein microarrays.		

Course Outcomes:

After successfully completing this course, students will be able to

1. Understand the fundamentals of nanodevices and fabrication process.
2. Evaluate the techniques for adopting nanodevices for medical and environmental applications.
3. Develop nanodevices for various applications from basic principles.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. James E. Morris, Krzysztof Iniewski, Nanoelectronic Device Applications Handbook, CRC Press, Taylog& Francis Group, ISBN 9781138072596, 2017 (Selected Chapters
2. Jun Li, Nianqiang Wu, Biosensors Based on Nanomaterials and Nanodevices, CRC Press, Taylog& Francis Group, 2014

References:

1. Challa S. S. R. Kumar, Nanodevices for the Life Sciences, Wiley-VCH Verlag GmbH, 2006

M.Tech., Nanotechnology [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2020 -2021) SEMESTER - III			
Course Title	**Nanotechnology in Food and Agriculture**	**Code**	**20INT334**
Teaching Hours/Week (L:P:SDA)	4:0:0	CIE Marks	40
Total Number of Lecture Hours	50	Exam Marks	60
Credits	04	Exam Hours	03

Course Learning Objectives:

1. To understand the nanoparticles used in food and agriculture for diagnostic purpose
2. To study the application of nanoparticles and technology for production
3. To understand the technology issues to implement the use of Nanomaterials and technology in food and agriculture

Module	**Content**	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
1	Introduction: Rhizosphere, Emulsions, Surfactants-Biodegradable and non biodegradable, Pesticides, Insecticides, Herbicides, Weedicides, Biomagnification, Micro and Macro nutrients required by plants. Various types of nanomaterial utilized in agriculture, Soil health-Different Indicators (Assays) for determining soil health.	10	L1, L2, L3
2	Nanoparticles in agricultural and food diagnostics: Enzyme Biosensors and Diagnostics - DNA-Based Biosensors and Diagnostics Radiofrequency IdentificationIntegrated Nanosensor Networks: Detection and Response- Lateral Flow (Immuno)assay - Nucleic Acid Lateral Flow (Immuno)assay - Flow-Through (Immuno)assays - Antibody Microarrays Surface Plasmon Resonance Spectroscopy	10	L1, L2, L3
3	Nanotechnology in food production: Food and New Ways of Food Production - Efficient Fractionation of Crops Efficient Product Structuring -Optimizing Nutritional Values - Applications of Nanotechnology in Foods : Sensing, Packaging, Encapsulation, Engineering Food Ingredients to Improve Bioavailability - Nanocrystalline Food Ingredients - NanoEmulsions - Nano-Engineered Protein Fibrils as Ingredient Building Blocks Preparation of Food Matrices - Concerns about Using Nanotechnology in food production.	10	L1, L2, L3, L4
4	Nanotechnology in food packaging: Crop improvement - Reasons to Package Food Products - Physical Properties of Packaging Materials - Strength - Barrier Properties Light	10	L1, L2, L3, L4

	Absorption – Structuring of Interior Surfaces - Antimicrobial Functionality - Visual Indicators – Quality Assessment - Food Safety Indication - Product Properties - Information and Communication Technology - Sensors - Radiofrequency Identification Technology Risks - Consumer and Societal Acceptance.		
5	Technology Issues: Life Cycle of Nanotechnology Food Products, Molecules in Foods Involved in Triggering Allergies, Food Structure, Processing, and Food Allergy, Impact of Nanoscale Structures on Allergenic Potential of Foods, Innovations in Food and Agriculture Nanotechnology.	10	L1, L2, L3, L4

Course Outcomes:

The Student will be able to demonstrate the knowledge of nanotechnology and various nanomaterials in food and agricultural applications.

Question paper pattern:

- Examination will be conducted for 100 marks with question paper containing 10 full questions, each of 20 marks.
- Each full question can have a maximum of 4 sub questions.
- There will be 2 full questions from each module covering all the topics of the module.
- Students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Lynn J. Frewer, Willem Norde, Arnout Fischer, Frans Kampers “Nanotechnology in the Agri-Food Sector” John Wiley and Sons,2010
2. S.Choudhary, ‘Applied Nanotechnology in Agriculture’, Arise Publication, 2011.
3. Nanoparticle Assemblies and Superstructures by Nicholas A. Kotov, CRC, 2006.
4. Nanotechnology in agriculture and food production by Jennifer Kuzma and Peter VerHage,, Woodrow Wilson International, 2006.
5. Bionanotechnology by David S Goodsell, John Wiley & Sons, 2004. 4) Nanobiomaterials Handbook by Balaji Sitharaman, Taylor & Francis Group, 2011.