KANNUR UNIVERSITY

(Abstract)

M Sc Nanoscience & Nanotechnology Programme at Dept.of Chemistry, School of Chemical Sciences, Swami Ananda Theertha Campus, Payyanur - Revised Scheme & Syllabus - Approved- Implemented w.e. f.2023 admission- Orders Issued

ACADEMIC C SECTION

ACAD C/ACAD C3/23802/2023 Dated: 20.12.2023

Read:-1. UO No ACAD C/ ACAD C3/22373/2019 dated 12/09/2023
2. Circular No dated ACAD C/ ACAD C3/22373/2019 dated 12/09/2023
3. Email dated 24/11/2023 from the Coordinator, Nanoscience & Nanotechnology- Dept of Chemistry, SAT Campus, Payyanur
4. Email dated 07/12/2023 from the Coordinator, Nanoscience & Nanotechnology- Dept of Chemistry, SAT Campus, Payyanur
5. Minutes of the meeting of the Department Council dated 09/11/2023

ORDER

1.The revised Regulations for Post Graduate Programmes under Choice Based Credit and Semester System in the University Teaching Departments/ Schools were implemented w.e.f 2023 admissions vide paper read 1 above

2. As per paper read 2 above, Heads of all Teaching Departments were requested to submit the revised Syllabus in accordance with the approved Regulations along with a copy of the Department Council Minutes.

3. As per paper read 3 above, the Co-ordinator, Nanoscience, Department of Chemistry, School of Chemical Sciences, SAT Campus, Payyanur submitted the Scheme and Syllabus of M.Sc Nanoscience & Nanotechnology Programme to be implemented in the University Teaching Department w.e.f 2023 admissions, prepared on the basis of workshop held participating subject expert Prof N Ponpandian, Dept of Nanoscience & Technology, Bharathiar University, Coimbatore , who served as the External Expert as well as Resource Person for the online workshop on Curriculum Revision of M.Sc Nanoscience & Nanotechnology Programme

5. Department Council vide the paper read 5 above approved the aforementioned scheme and syllabus of M.Sc Nanoscience & Nanotechnology Programme to be implemented in the Dept. of Chemistry at the School of Chemical Sciences of the University w.e.f.2023 admission.

6. The Vice Chancellor, after considering the matter in detail and in exercise of the powers of the Academic Council conferred under section 11(1), Chapter lll of Kannur University Act 1996, ***approved the revised Scheme & Syllabus of M.Sc Nanoscience & Nanotechnology Programme and accorded sanction to implement the same in the Department of Chemistry, School of Chemical Science, SAT Campus, Payyanur, subject to reporting to the Academic Council.***

7.The revised Scheme and Syllabus of M.Sc Nanoscience & Nanotechnology Programme under CBCSS implemented in the Department of Chemistry, School of Chemical Sciences, SAT Campus, Payyanur with effect from 2023 admission, is appended and uploaded in the University website (www.kannuruniversity.ac.in)

8. Orders are issued accordingly.

Sd/-
Narayanadas K
DEPUTY REGISTRAR (ACAD)
For REGISTRAR

To:
1. Head, Department of Chemistry, SAT Campus, Payyanur
2. Convenor, Curriculum Committee
3. Programme Coordinator, Nanoscience & Nanotechnology

Copy To:
1.PS to VC/ PA to PVC/ PA to R
2. To Examination Branch (through PA to CE)
3. EP IV/ EXC I
4. Computer Programmer
5. Webmanager (to publish on the website)
6. SF/DF/FC

KANNUR UNIVERSITY * CIVIL STATION P.O. KANNUR Pin-670 002 * THAVAKKARA *

Forwarded / By Order
SECTION OFFICER

KANNUR UNIVERSITY

Scheme and Syllabus

for

M.Sc. PROGRAMME

in

Nano science and Nano technology

Choice Based Credit and Semester System

w.e.f 2023 Admission

School of Chemical Sciences

KANNUR UNIVERSITY

Swami AnathaTheertha Campus

Edat P.O 670327, Kannur

September 2023

M.Sc. DEGREE PROGRAMME IN NANOSCIENCE AND NANOTECHNOLOGY

Under Choice Based Credit and Semester System)

(Effective from 2023 Admission)

About the Department

The School of Chemical Sciences and school of Pure and Applied Physics was established in 2002 and is housed at the Payyanur Campus of the University located at Edat, Payyanur. The School is offering M.Sc Chemistry (Material Science), MSc Nanoscience and Nanotechnology, a Joint Programme M.Sc. Chemistry (Nanoscience and Nanotechnology) MG University Kottayam, Ph.D. in Chemistry, and Biochemistry. The pattern of M.Sc. programme pattern is of Choice based Credit and Semester System consisting of four semesters including one semester project work. The M.Sc Chemistry (Material Science) and M.Sc. Chemistry (Nanoscience and Nanotechnology) programmes are equivalent to MSc Chemistry of Kannur University. The School of Chemical Sciences and Physics are having an excellent Library with latest editions of textbooks, reference books and relevant journals in chemistry, Physics. nanoscience and material science. Library also providing internet facility to students. Fourth semester M.Sc. students carry out their project works in reputed national Institutes.

1	The MSc programme shall be offered in four semesters during a period of two academic years. Each semester will have 17-18 weeks duration. The minimum duration for completion of the programme is four semesters. The maximum period for the completion of the programme is eight semesters.
2	The programme is offered at the School of Chemical Sciences, Swami Anantha Theertha Campus of Kannur University situated at Edat, Payyanur.
3	A total of 80 credits shall be the minimum for successful completion of the course in which a minimum of 60 credits for core course and 12 credits for electives are mandatory. Those who secure only minimum credit for core/ elective subjects has to supplement the deficiency for obtaining the minimum total credits required for successful completion of the program from the other divisions.

4	The number of periods allotted per week for a topic is considered as its credit. For practical, three hours is considered as one credit. Elective courses will be offered depending on the availability of the teaching staff/resource person at that time. At least 6 students have to register for an offered elective course.
5	No students shall register for more than 24 credits and less than 16 credits per semester. The duration of the course shall extend to more than two years (maximum four years) for the students securing less than 12 credits in a semester.
Programme details:	
1	In first and second semester, there will be 4 core courses and one elective course. In Third semester there will be 4 core courses and 2 elective courses each. In Fourth semester, there will be 3 core courses and 2 elective courses. An open elective course is offered to other Department students in the third semester. A value-added course is offered in the second semester.
2	During the fourth semester, the students will have to visit a Research Institute of National repute to have an idea about the current research activities. The report of the same may be submitted to the Head of the department for valuation.
3	During the fourth semester, each student shall carry out project work in any branches of Nano Science for a period of not more than six months under the supervision of a teaching staff of the Department nominated by the Head of the department. The departmental council shall make decisions regarding the project details.
4	A student will have to present one seminar (two credit) in the fourth semester. The topics of the seminar will be chosen by the student in concern with his/her tutor.
5	Attendance is compulsory for each course and the minimum requirement for appearing for the end semester examination shall be as per general regulations of M.Sc. programme of the University.
6	Open elective means an elective course which is available for students of all programmes, including students of the same department. Students of other Department will opt these courses subject to fulfilling the eligibility of criteria as laid down by the Department offering the course.

7	One hour per week is allotted for tutorial classes. Each student will be assigned to a teaching staff of the department as his/her advisor.

PROGRAMME OUTCOMES	
PO 1	**Critical Thinking:** Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.
PO2	**Problem Solving:** Identify, formulate, conduct investigations, and find solutions to problems based on in-depth knowledge of relevant domains.
PO 3	**Communication:** Speak, read, write and listen clearly in person and through electronic media in English/language of the discipline, and make meaning of the world by connecting people, ideas, books, media and technology.
PO 4	**Responsible Citizenship:** Demonstrate empathetic social concern, and the ability to act with an informed awareness of issues.
PO 5	**Ethics**: Recognize different value systems including your own, understand the moral dimensions of your decisions, and accept responsibility for them.
PO 6	**Self-directed and Life-long Learning:** Acquire the ability to engage in independent and life-long learning in the broadest context socio- technological changes.
PO 7	**Environmental Sustainability and Global Perspective:** Develop an understanding of global standards to foster legal environment. Learn and practice to critically analyze the legal issues from local, national and international concerns.
PROGRAMME SPECIFIC OUTCOMES	
At the end of the Programme student will be able to:	

PSO1	Explain the fundamentals and opportunities of Nanoscience and Nanotechnology.
PSO2	Analyze different theories of chemistry for application in the field of nanomaterial development.
PSO3	Perform a critical analysis of benefits and potential negative impacts of nanotechnology on environment and society.
PSO4	Design, synthesize and characterize the advanced nanomaterials for various applications.
PSO5	Demonstrate skills required according to the demand/need of changing trends of modern Industries.

SEMESTER I

No	Course Code	Topic	Contact Hours/week			Marks			Credits
			L	T/S	P	ESE	CE	Total	
CORE COURSES									
1	MSNST01DSC01	Quantum and Statistical Mechanics	4	-	-	60	40	100	4
2	MSNST01DSC02	Structure and Bonding in Solids	4	-	-	60	40	100	4
3	MSNST01DSC03	Fundamentals of Nanoscience	4	-	-	60	40	100	4
4	MSNST01DSC04	Environmental Impacts of Nanotechnology	4	-	-	60	40	100	4

5	MSNST01DSC05	Nano Lab – I	-	-	12	60	40	100	4
Total			28					**500**	**20**

SEMESTER II

No	Course Code	Topic	Contact Hours/week			Marks			Credits
			L	T/S	P	ESE	CE	Total	
CORE COURSES									
6	MSNST02DSC06	Design and Synthesis of Nanomaterials	4	-	-	60	40	100	4
7	MSNST02DSC07	Characterization Techniques for Nanomaterials	4	-	-	60	40	100	4
8	MSNST02DSC08	Nano Lab – II	-	-	12	60	40	100	4
Total for core courses			20					300	12
ELECTIVE COURSES									

9	MSNST02DSE01	Elements of Physical Chemistry	2x3	-	-	60	40	100	6
10	MSNST02DSE02	Nanoscale Magnetic Materials and Devices							
11	MSNST02DSE03	Nanomaterials for Energy and Environment							
12	MSNST02DSE04	Nanomaterials in Everyday Life							
13	MSNST02DSE05	Polymer Science							
14	MSNST02DSE06	Nanopharmaceuticals							
INTERDISCIPLINARY COURSES									
15	MSNST02IDC01	Composite Materials **(offered to other departments)**	2	-	-	60	40	100	2
16	MSNST02IDC02	Nanobiomaterials **(offered to other departments)**							
17	MSNST02IDC03	Nanotechnology and Waste Management							

		(offered to other departments)							
	------	**To be obtained from other departments**							
SKILL ENHANCEMENT COURSES									
18	MSNST02SEC01	Scientific Analysis and Data Collection **(offered to other departments)**	2	-	-	60	40	100	2
19	MSNST02SEC02	Technical Writing **(offered to other departments)**							
20	MSNST02SEC03	Laboratory Skills and Practices **(offered to other departments)**							
-------		**(To be obtained from other departments)**							
VALUE ADDED COURSES									
	MSNST02VAC01	Certificate course in Advanced Techniques for Characterization of Materials (Value -	2	-	-	60	40	100*	2*

		added course)							
Total			32					**800**	**22**
**** Not to be added to the total marks and credits***									

SEMESTER III

No	Course Code	Topic	Contact Hours/week			Marks			Credits
			L	T/S	P	ESE	CE	Total	
CORE COURSES									
21	MSNST03DSC09	Semiconductor Nanomaterials and Nanolithography	4	-	-	60	40	100	4
22	MSNST03DSC10	Carbon Nanostructures	4	-	-	60	40	100	4
23	MSNST03DSC11	Nanobiotechnology	4	-	-	60	40	100	4
24	MSNST03DSC12	Research Project	-	-	12	60	40	100	4
25	MSNST03DSC13	Industrial Visit	-	-	-	-	-	100	2
Total for core courses			24					**500**	18

ELECTIVE COURSES									
26	MSNST03DSE07	Nano Medicine and Drug Delivery Systems	1x3	-	-	60	40	100	3
27	MSNST03DSE08	Organic Nanomaterials							
28	MSNST03DSE09	Nanophotonics							
MULTIDISCIPLINARY ELECTIVE COURSES									
	--------	Multi Disciplinary Elective course (to be obtained from other departments)	4	-	-	60	40	100	**4**
29	MSNST03MDC01	Introduction to Nanotechnology (Multidisciplinary Elective course Offered to Students from other Departments of Kannur University)							
Total			**31**					**700**	**25**

SEMESTER IV

No	Course Code	Topic	Contact	Marks	Credit

			Hours/week						s
			L	T/S	P	ESE	CE	Total	
CORE COURSES									
30	MSNST04DSC14	External Research Project		-	30	60	40	100	10
Total for core courses			30					**100**	10
ELECTIVE COURSES									
31	MSNST04DSE10	Industrial Significance and Applications of Nanotechnology	2 x3	-	-	60	40	200	6
32	MSNST04DSE11	Nanoelectronics							
33	MSNST04DSE12	Nanotechnology-Society, Ethics and Legal Aspects							
34	MSNST04DSE13	Prospects and Challenges of Nanotechnology							
35	MSNST04DSE14	Nanosensors and their Applications							

36	MSNST04DSE15	Nanorobotics							
		Total	36					**300**	**16**

Grant Total		
Marks: 2300	**Core Credits: 60**	**Elective Credits: 23**

Course code- MSNST: Master of Science Nano science and Nano Technology; DSC: Discipline Specific Core; DSE: Discipline Specific Elective; MDC: Multidisciplinary Course: IDC: Interdisciplinary Course

Semester I								
Core Course								
Course Code: **MSNST01DSC01**			Course Name: **Quantum and Statistical Mechanics**					
Course Description								
This course gives a broad, theoretical treatment of classical mechanics. This course also deals with basic principles and theories of quantum mechanics and statistical mechanics. This course is essential to understand the different concepts in quantum and statistical mechanics and their application to simple systems.								
Course Objectives								
1 To study the equilibrium and motion of bodies subject to forces 2 To provide the theoretical framework to describe and predict the motions of bodies. 3 To explore the statistical methods and probability theory to large assemblies of microscopic entities. 4 To have a clear idea on different types of statistics. 5 To understand the basics of quantum mechanics and apply to simple systems.								
Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
4	0	4	72	0	72	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Apply basic concepts of Classical Mechanics to different systems.
C02	Formulate equations of motion for complicated mechanical systems of classical

	mechanics.
C03	Show an analytic ability to solve problems relevant to statistical mechanics.
C04	Apply the basis of quantum mechanics to simple systems.
C05	Construct the Schrödinger equations for simple systems.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No of hrs
1.0	**Classical Mechanics**	**18hrs**
1.1	Basic Principles of Classical Mechanics – Conservation laws, Conservation of Angular Momentum and Energy - Generalized and Cyclic Co-ordinates – Limitations of Newton's Law -Constraints-classification of constraints.	
1.2	Hamilton's equations from Variational Principle - D' Alemberts Principle-Hamilton's principle – Lagrange Equations-Derivation of Lagrange's Equations from D' Alemberts Principle and Hamilton's Principle.	
1.3	Simple Application of Lagrangian Equation – Motion of one particle in space using cartesian and plane polar coordinates-Atwood's machine- Bead sliding on a rotating wire.	
1.4	Hamiltonian's Canonical Equations of Motion-Compound Pendulum- Simple Pendulum- Particle in a Central Field of Force.	
Suggested Reading Specific to the module		
1.1	Classical Mechanics, Kibble, T. W.; Berkshire, F. H. Imperial College Press, (2004).	
1.2	Classical Mechanics, Taylor, John., University Science Books, (2005).	
1.3	Classical Dynamics of Particles and Systems (5th ed.), Marion, Jerry; Thornton, Stephen, Brooks Cole (2003).	
1.4	Classical Mechanics, L.S. Gupta, V. Kumar, and H.V. Sharma, Pragati	

	Prakashan Publication (2007)
2.0	**Statistical Mechanics 18hrs**
2.1	Fundamentals of Statistical Mechanics: Phase Space – Ensembles: Types of Ensembles – Microcanonical, Canonical, Grand Canonical Ensembles - Uses of Ensembles.
2.2	Microstates and Macro States-Calculation of macrostates and microstates for different arrangements. Thermodynamic probability-Distribution and Arrangement of particles
2.3	Stirling's Approximation – Distinguishable and indistinguishable particles-Bosons-Boltzons-Fermions-Number of possible arrangements.
2.4	Classical statistics: Maxwell-Boltzmann Distribution Law – Quantum Statistics -Bose-Einstein Distribution Law - Fermi-Dirac Distribution Law – Comparison of the Three Distribution Laws.
Suggested Reading Specific to the module	
2.1	Statistical Mechanics (4th ed.), Pathria, P. K.; Beale, Paul, United States: Elsevier/Academic Press (2021).
2.2	Introductory Statistical Mechanics, Bowley, Roger and Sanchez, Mariana, Oxford University Press (2000).
2.3	Statistical Mechanics 2nd Edition by Huang, Wiley India (1988)
2.4	Elements of statistical Thermodynamics, L.K. Nash, Addision Wesley Publishing
3.0	**Quantum Mechanics – I 18hrs**
3.1	Basis of Quantum Mechanics – Classical mechanics and its limitations –need of quantum mechanics. De Broglie's Concept – Operators – Algebra of operators, Commutator, Linear, Laplacian, Hamiltonian and angular

	momentum operators.
3.2	Hermitian property- Heisenberg's Uncertainty Principle -Wave Function-Normalized - Orthogonal and orthonormal Wave Function - Eigen values and Eigen Function-Postulates of quantum mechanics- time dependent and time independent Schrodinger equations.
3.3	Quantum mechanics of translational motion- Applications to simple systems-Particle in a box-Three-dimensional box- rectangular box-Cubical Box-Degeneracy-
3.4	Quantum mechanics of vibrational motion- one-dimensional harmonic oscillator – Hermite polynomial- comparison of classical and quantum mechanical results.
Suggested Reading Specific to the module	
3.1	Introduction to Quantum Mechanics, L. Pauling and W.B. Wilson, McGraw Hill.
3.2	Quantum chemistry, I. N. Levine, Pearson Education
3.3	David J. Griffiths, Darrell F. Schroeter, Introduction to Quantum Mechanics (Third edition), Cambridge University Press India Pvt Ltd, (2019)
3.4	Quantum Mechanics in Chemistry, M. W. Hanna, Benjamin, 3rd Edn.
4.0	**Quantum Mechanics – II** **18hrs**
4.1	Quantum mechanics of Hydrogen atoms- The wave equation in spherical polar coordinates - Energy Eigen value- Solution of the R,θ,Ø equations- Laguerre and Associated Laguerre Polynomials.
4.2	Angular Momentum – Total Angular Momentum Operators – Commutation Relationship with Components.
4.3	Need of approximate methods in quantum chemistry- Variation Method-Application to simple systems-Energy of one-dimensional box using variation

	method. Linear Variation functions.
4.4	Perturbation Method-First order perturbation-Correction to energy- Correction to wavefunction-Application of perturbation theory to simple systems.
Suggested Reading Specific to the module	
4.1	Fundamentals of Quantum chemistry, R Anantharaman, Macmillan.
4.2	Molecular Quantum Mechanics, P.W. Atkins, R.S. Friedmann, Oxford University Press.
4.3	Quantum chemistry, I. N. Levine, Pearson Education
4.4	Introductory Quantum chemistry, A.K. Chandra, Tata McGraw Hill.

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Classical Mechanics, L.S. Gupta, V. Kumar, and H.V. Sharma, Pragati Prakashan Publication (2007).
2 Statistical Mechanics, by Gupta and Kumar, Pragati Prakashan Publication.
3 Quantum Mechanics – Satya Prakash and C. K Singh Kedar Nath and Ram Nath Co
4 Quantum Mechanics – G. Aruldhas – Princitan Hall of India, New Delhi.
5 Quantum chemistry, R K Prasad, New Age International

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Classical Mechanics, H. Goldstein, Charless Poole and John Safco, Addison Wesley (2000)
2 Modern Physics and Quantum Physics – E.E Anderson, Macmillan Co., India
3 Quantum chemistry, D.A. McQuarrie, University Science Books.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Construct the Lagrangian equation of motion from D'Alemberts principle.

2 Discuss the application of lagrangian equation.

3 Compare the salient features of both Bose-Einstein statistics and Fermi- Dirac statistics.

4 Evaluate the macrostates and microstates for tossing three coins.

5 Setup and solve Schrodinger equation for a particle in 1-D box and normalize the wave function

6 Apply the Quantum mechanical treatment to the simple harmonic oscillator.

7 Use perturbation method to find the first order correction in energy and wave function if a particle in 1D box is subjected to a uniform electric field of strength F.

8 Discuss the various approximation method in quantum mechanics

Semester I	
Core Course	
Course Code: **MSNST01DSC02**	Course Name: **Structure and Bonding in solids**
Course Description	
The course is divided into four modules. Each module describes the concepts in solid state. The various theories related to the structure and bonding in molecules – VSEPR, CFT and M.O, classifications of solids and their related theories are elaborately considered. Ionic solid formation, its type with examples are also included in module one. Basics of crystallography, Crystal systems in 2D and 3D, symmetry elements and operations present in crystal system, symmetry of molecules, crystal plane representation are included. Different types of imperfections found in solids, crystal growth mechanisms, theories related to growth, growth kinetics, different growth methods and deformations during growth are included in the third	

module. Designing of new materials, structural rearrangements, structural distortions are included in fourth module.

Course Objectives

1. To understand the fundament al theories in soli d state - VB, CFT and MO Theory.
2. To understand the concept of bonding in solids and how it determines their properties.
3. To develop an understanding of different crystal systems, their structure and symmetry.
4. To provide knowledge related to the mechanism and conditions of crystal growth, different methods involved and the types of imperfections and deformations occurring during growth.

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
4	0	4	72	0	72	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Remember the bonding concepts and postulates of various theories.
C02	Explain and understand the shape of the molecule, hybridization and their structural distortions.
C03	Understand different crystal system, lattices in 3D and 2D, planes and the symmetry present in crystals and molecules.
C04	Predict the symmetry elements present in molecules and the point group.
C05	Understand the imperfections formed in crystals during growth, crystal transformations, deformations etc.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Chemical Bonding**	**22 hrs**
1.1	Types of chemical bonds, the octet rule, Wave Mechanical picture of chemical bonding. Ionic solids, lattice energy, Born- Lande equation, typical structures – AB, AB_2,A_2B type, bonding considerations, radius-ratio concept, electrical neutrality, bond types- ionic, covalent metallic and Vander Waals interactions.	
1.2	Structural distortions, types, examples, consequence of d-electron configuration on structure.	
1.3	VSEPR theory, shape of the molecules, hybridization, crystal field theory, splitting in Oh, Td, Sq complexes, CFSE calculation, MO theory, MO description of select ML_6 ,(Octahedral □□ and □□ bonding); ML_4 (Tetrahedral, square-planar) - based structures, band structure.	
1.4	Characteristic properties of metals, crystalline and amorphous solids, Classification of solids into insulators, semiconductors, conductors and super conductors, Theories of bonding in solids - The free electron theory, Band and Zone Theories, the Kronig-Penny model.	
Suggested Reading Specific to the module		
1.1	Atomic structure and chemical Bond, Manas Chanta **Publisher:** McGraw-Hill Inc.,US (1 December 1974) **ISBN-10:** 0070965110	
1.2	Concise Inorganic chemistry, J.D.Lee **Publisher:** Wiley; 5th edition edition (18 December 1998) **ISBN-10:** 0632052937	
1.3	Inorganic Solids, D.M. Adams, John Wiley&Sons, NewYork, 1974	
1.4	Inorganic Chemistry, G. Wwfsberg Unit IV **Publisher:** Pearson; 4 edition (31 May 2012) **ISBN-10:** 0273742752	

2.0	**Crystallography** **16 hrs**
2.1	Periodicity in crystals, translational periodicity, representation of a lattice, notations of planes in a lattice, Weiss indices, miller indices, relationship between planes- interplanar distance and angle between planes.
2.2	Crystal types, two and three-dimensional crystal lattices.
2.3	Symmetry elements – proper and improper rotation axes, screw axes, glide planes. Symmetry groups- point groups, Schonflies system and Hermann – Mauguin system. categories of crystal, plane groups, space lattices, space groups, super groups and subgroups.
2.4	Point groups in molecules - $C_{nv,}$ D_{nh}, $C_{\square v}$, $D_{\square h}$, C_{nh}, C_1, C_s, C_i
	Suggested Reading Specific to the module
2.1	Principle of Physical Chemistry, B.R. Puri,L.R. sharma, Madan. S. Pathania.
2.2	Elements of solids state physics, J.P. Srivastava, **Publisher:** Prentice Hall India Learning Private Limited; 4th Revised edition edition (17 December 2014) **ISBN-10:** 8120350669
2.3	Introduction to solids – L.V. Azaroff, **Publisher:** McGraw Hill Education; New edition edition (14 June 2001) **ISBN-10:** 0070992193
2.4	Chemical application of group theory, F.A. Cotton.
3.0	**Imperfections in solids** **20 hrs**
3.1	Types of Imperfections - classification. Point defects - Schottky defects, Frenkel defect, Disordered Crystal. Line defects - Dislocation types, Dislocation theory. Plane defect - Large- angle boundaries, Small – angle boundaries, stacking faults. Colour centers in alkali halides.
3.2	Crystal growth, types- growth from melt (Bridgman, Czochralski, Verneuil, Zone Melting, Kyropoulos, Skull Melting Process), growth from solution (hydrothermal, low temperature solution growth), growth from vapour (CVD,

	PVD), Solid-state single crystal growth.
3.3	Twinning - Growth, Deformation and transformation twins, twin laws. - Velocity, Theories and Mechanism of crystal growth. Twinning - Growth, Deformation and transformation twins.
3.4	Transformations in Crystals - Equilibrium transformations, Kinetics of transformations Elastic deformation and plastic deformation in crystals.
Suggested Reading Specific to the module	
3.1	Principle of Physical Chemistry, B.R. Puri,L.R. sharma, Madan. S. Pathania.
3.2	Introduction to crystal growth Principles and Practice, H.L. Bhat.
3.3	Introduction to solids – L.V. Azaroff, **Publisher:** McGraw Hill Education; New edition edition (14 June 2001) **ISBN-10:** 0070992193
3.4	Introduction to solids – L.V. Azaroff, **Publisher:** McGraw Hill Education; New edition edition (14 June 2001) **ISBN-10:** 0070992193
4.0	**Design of New Materials** **14 hrs**
4.1	Design of new materials – Chemical bonding considerations- chemical nature of substituents and dopants
4.2	ns^2 lone pair influence, local structural rearrangements, structural distortions, mixed valence, defect-chemistry tailoring.
4.3	Pauling rule-application to actual structures, variations in atomic packing-polymorphism, isomorphism, solid solutions, derivative structures, Alloys, ceramics, composite materials and conducting polymers.
Suggested Reading Specific to the module	
4.1	Concise Inorganic chemistry, J.D.Lee **Publisher:** Wiley; 5th edition edition (18 December 1998) **ISBN-10:** 0632052937

4.2	Concise Inorganic chemistry, J.D.Lee **Publisher:** Wiley; 5th edition edition (18 December 1998) **ISBN-10:** 0632052937
4.3	Introduction to solids – L.V. Azaroff, **Publisher:** McGraw Hill Education; New edition edition (14 June 2001) **ISBN-10:** 0070992193

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1 Atomic structure and chemical Bond, Manas Chanta **Publisher:** McGraw-Hill Inc.,US (1 December 1974) **ISBN-10:** 0070965110
2 Concise Inorganic chemistry, J.D.Lee **Publisher:** Wiley; 5th edition edition (18 December 1998) **ISBN-10:** 0632052937
3 Inorganic Chemistry, G. Wwfsberg Unit IV **Publisher:** Pearson; 4 edition (31 May 2012) **ISBN-10:** 0273742752
4 Introduction to solids – L.V. Azaroff, **Publisher:** McGraw Hill Education; New edition edition (14 June 2001) **ISBN-10:** 0070992193
5 Inorganic Solids, D.M. Adams, John Wiley&Sons, NewYork, 1974
6 Materials Science and Engineering, V.Raghavan, PHI L Pvt.Ltd.,N.Delhi,2015

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Introduction to solid state Physics – C. Kittel, **Publisher:** John Wiley & Sons Inc (23 July 1996), **ISBN-10:** 0471142867
2 Elements of solids state physics, J.P. Srivastava, **Publisher:** Prentice Hall India Learning Private Limited; 4th Revised edition edition (17 December 2014) **ISBN-10:** 8120350669

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks

End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Explain sigma and pi bonding in octahedral complexes using MOT.

2 Discuss about the structural distortions observed in transition metal complexes.

3 Predict the point groups of benzene, pyridine and 1,3-dichloro benzene.

4 Discuss in detail about the crystal systems in 2D and 3D.

5 Write a note on atomic imperfections in solids.

Semester I								
Core Course								
Course Code: **MSNST01DSC03**			Course Name: **Fundamentals of Nanoscience**					
Course Description								
The course is divided into four modules. Each module describes the basic concepts in nanoscience. The elementary concepts of nanoscience such as the evolution of the same as a branch of science, size dependent properties of nanomaterials etc. are elaborately considered. The classifications of different kinds of nanomaterials are also included. The basic aspects of surface energy and stabilization mechanisms are also depicted in detail.								
Course Objectives								
1. To acquire awareness on the importance of Nano-technology, Emergence of Nanoscience and technology and challenges in Nanotechnology. 2. To gain understanding of physical chemical and mechanical properties of low dimensional systems. 3. To understand the basic science required to know the fundamentals of nanostructures and their types. 4. To give a detailed overview on special nanomaterials. 5. To provide the basic concepts on surface energy of nanomaterials and its significance.								
Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**

4	0	4	72	0	72	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the fundamentals and opportunities of Nanoscience and Nanotechnology.
C02	Interpret specific properties of nanomaterials in the Nano-regime
C03	Classify different types of nanostructures based on quantum confinement.
C04	Explain the trends in properties of materials with variation in particle size.
C05	Summarize stabilization mechanisms of nanomaterials.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Fundamentals of Nanomaterials**	**12**
1.1	History of Nanotechnology – Major milestones, Feynman's vision on nanoscience & technology,	
1.2	bulk vs nanomaterials. Central importance of nanoscale morphology	
1.3	Nanomaterials in nature- Gecko feet, peacock feather, Blue morpho butterfly, Lotus effect,	
1.4	clusters and magic numbers- Jellium model, Recent developments, challenges and future prospects of nanomaterials.	
Suggested Reading Specific to the module		
1.1	Sharon, Madhuri, ed. History of nanotechnology: from prehistoric to modern times. John Wiley & Sons, 2019.	
1.2	Shah, M. A., and K. A. Shah. Nanotechnology: The Science of Small. Vol. 200. Hoboken, NJ: Wiley, 2019.	
1.3	R. Kelsall, I.Hamley and M. Geoghegan, Nanoscale Science and Technology, Wiley, 2005	
1.4	Edelstein, Alan S., and R. C. Cammaratra, eds. Nanomaterials: synthesis, properties and applications. CRC press, 1998.	
2.0	**Size and shape dependent properties of nanomaterials**	**20**

2.1	Size and shape dependent properties, Melting points and lattice constants, Surface Tension, density of states, Wettability - Specific Surface Area and Pore – Composite Structure -
2.2	Mechanical properties-Hall Ptech and Inverse Hall-Petch Relationships, Orowan strengthening etc
2.3	Optical properties of metal nanoparticles: Surface plasmon resonance in-various parameters that affect the SPR- application of SPR; Optical properties of Semiconductor Nanoparticles: Quantum confinement effect in in Semiconductors
2.4	Electrical conductivity: Surface scattering, change of electronic structure, Ballistic transport, Coulomb Blockade effect, effect of microstructure.
2.5	Magnetic properties: Single domain structure and superparamagnetism., Ferroelectrics, dielectrics in the nano-regime
Suggested Reading Specific to the module	
2.1	G. Cao and Y.Wang, Nanostructures and Nanomaterials, 2nd Ed., Imperial College Press, 2004.
2.2	Chemistry of nanomaterials: Synthesis, properties and applications by CNR Rao et.al. Wiley VCH, Verlag Gmbh & Co, Weinheim
2.3	Zhang, Jin Zhong. Optical properties and spectroscopy of nanomaterials. World Scientific, 2009.
2.4	Zhang, Jin Zhong. Optical properties and spectroscopy of nanomaterials. World Scientific, 2009.
2.5	T. Pradeep, A text book of Nano Science and Technology, Tata McGraw-Hill Education, 2012
3.0	**Classification of nanomaterials** **20**
3.1	Classification based on the dimensionality, Zero-dimensional nanostructures: metal, semiconductor and oxide nanoparticles.
3.2	One-dimensional nanostructures: nanowires and nanorods, Two-dimensional nanostructures: Thin films, Three-dimensional nanomaterials.
3.3	Special Nanomaterials: Carbon base materials like Graphene, fullerenes and carbon nanotubes-evolution, synthesis and applications
3.4	Special Nanomaterials: micro and mesoporous materials- synthesis and

	classifications, core-shell structures, organic-inorganic hybrids-classification and methods of synthesis.
	Suggested Reading Specific to the module
3.1	Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2005
3.2	G. Cao and Y.Wang, Nanostructures and Nanomaterials, 2nd Ed., Imperial College Press, 2004.
3.3	Nanomaterials: An introduction to synthesis, properties and application, Dieter Vollath, WILEY-VCH, 2008
3.4	Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens
4.0	**Stabilization of nanomaterials** **20**
4.1	Surface science for nanomaterials, surface energy, stabilization mechanisms, Wulff plot, Surface roughening
4.2	electrostatic stabilization – Surface charge density, Nernst Equation, electric double layer, Van der Waals attraction potential, Debye-Huckel Screening strength. Interaction between nanoparticles – DLVO Theory
4.3	Steric stabilization- effects of solvents and polymers-electrosteric stabilization
4.4	nucleation and growth of nuclei, critical radius, homogenous and heterogeneous nucleation
	Suggested Reading Specific to the module
4.1	G. Cao and Y.Wang, Nanostructures and Nanomaterials, 2nd Ed., Imperial College Press, 2004.
4.2	Ramanathan Nagarajan, T. Allan Hatton, American Chemical Society. Meeting, Nanoparticles: Synthesis, Stabilization, Passivation, and functionalization, 2008
4.3	G. Cao and Y.Wang, Nanostructures and Nanomaterials, 2nd Ed., Imperial College Press, 2004.
4.4	C. N. R. Rao, Achim Müller, Anthony K. Cheetham, Nanomaterials Chemistry: Recent Developments and New Directions, Wiley VCH, 2007

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1. G. Cao and Y.Wang, Nanostructures and Nanomaterials, 2nd Ed., Imperial College Press, 2004.

2. R. Kelsall , I.Hamley and M. Geoghegan, Nanoscale Science and Technology, Wiley, 2005.
3. K. J Klabunde, R. M. Richards, Nanoscale Materials in Chemistry, 2nd Ed., Wiley, 2009.
4. T. Pradeep, A text book of Nano Science and Technology, Tata McGraw-Hill Education, 2012.
5. G. Schmidt, Nanoparticles: from Theory to applications, Wiley-VCH, 2004

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1. Murty, B. S., P. Shankar, Baldev Raj, B. B. Rath, and James Murday. Textbook of nanoscience and nanotechnology. Springer Science & Business Media, 2013
2. Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2005.
3. Richard C. Pleus, Vladimir Murashov, Physico-Chemical Properties of Nanomaterials, Jenny Stanford Publishing, 2018.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1. Show mathematically that the surface to volume ratio of nanoparticles is much higher than that of the bulk particle of theidentical material?
2. Briefly explain the progress of Nanotechnology over years?
3. How do you think biomimicry would help in developing a new tapebased on gecko feet?
4. Give an account on the challenges associated with Nanotechnology as anemerging field?
5. How does the arrangement of nanostructures affect the wettability in leaves?

6. Explain the Jellium model of clusters?
7. Write a note on structural colours with specific examples
8. Discuss the future prospects of Nanotechnology in the field of medicine?

Semester I	
Core Course	
Course Code: **MSNST01DSC04**	Course Name: **Environmental Impacts of Nanotechnology**
Course Description	
Nanomaterials have been proven to be useful in many environmental remediation applications. There are negative impacts also, such as health problems, relating to exposure to nanomaterials. This course deals with the benefits and negative impacts of nanomaterials to the environment and human beings. The course is divided into four modules. The first module discusses about the sources of nanoparticles and their entry route to human body. The second module deals with the positive impacts of implementing nanotechnology in environmental remediation. Toxicity of carbon nanotubes and metal oxide nanoparticles and their occupational health risks are discussed in third module. Fourth module deals with the effect of nanoparticles on specific human organs.	
Course Objectives	
1. To create awareness about the sources of nanoparticles, entry route to human body and their potential toxicity. 2. To make the students understand the environmental issues and the possible nanoparticle-based remediation strategies. 3. To understand the positive and negative effects of nanotechnology on the environment. 4. To create awareness about the toxicity of CNTs and metal oxides and their occupational exposure risk.	

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
4	0	4	72	0	72	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the sources of nanoparticles and their impact to human body and the health threats associated with it.
C02	Apply the knowledge of nanoparticle-based remediation materials in current environmental issues such as air, water and soil pollution.
C03	Analyze the possible occupational health risks of CNTs and metal oxides
C04	Perform a critical analysis of positive and negative aspects of nanotechnology on the environment.
C05	To differentiate toxicity of nanoparticles to specific organs in human body

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Possible Health Impact of Nanomaterials**	**18 hrs**
1.1	Sources of Nanoparticles; Epidemiological Evidence; Entry Routes into the Human Body – Lung, Intestinal Tract, Skin; Nano particle Size - Surface and Body Distribution; Effect of Size and Surface Charges	
1.2	Respiratory tract uptake and clearance of nanoparticles, Mucociliary escalator, Thrombosis and Lung Inflammation	

1.3	Nanoparticle-cell interactions, Nanoparticles and Cellular Uptake; Endocytosis-based uptake pathways: Clathrin-dependent endocytosis, Caveolin-dependent endocytosis, Clathrin- and caveolin-independent endocytosis, Phagocytosis, Macropinocytosis, Direct cellular entry of nanoparticles: Cytoplasmic entry by direct translocation, lipid fusion, Electroporation, Microinjection	
1.4	Nervous system uptake of nanoparticles, Structure and function of blood brain barrier, transport mechanisms of nanoparticles across Blood-Brain Barrier	
Suggested Reading Specific to the module		
1.1	Challa. S. S. R, Kumar, "Nanomaterials - Toxicity, Health and Environmental Issues", Wiley-VCH publisher, 2006	
1.2	Nancy. A, Monteiro-Riviere, Lang Tran. C, "Nanotoxicology: Characterization, Dosing and Health Effects", Informa healthcare, 2007	
1.3	Drobne. D, "Nanotoxicology for safe and Sustainable Nanotechnology", Dominant publisher, 2007	
1.4	Zafar Nyamadzi. M, "A Reference handbook of nanotoxicology", Dominant publisher, 2008	
2.0	**Nanomaterials for environmental remediation**	**18 hrs**
2.1	Introduction: Nanoparticle-based Remediation Materials,Metal-based nanomaterials, Silica-based Nanomaterials, Carbon-Based Nanomaterials, Polymer-Based Nanomaterials	
2.2	Acid-Base Chemistry, Redox Chemistry: Zero valent Iron, Absorption Chemistry	
2.3	Hybrid Nanostructured Remediation Materials, Nanostructured Metal Phosphonates: Iminodiacetic Acids and Related Chelating Ligands, Macrocycle Metal Phosphonates	
2.4	Self-assembled Monolayers on Mesoporous Supports (SAMMS): Actinide	

	SAMMS- Functional CNTs	
Suggested Reading Specific to the module		
2.1	Challa. S. S. R, Kumar, "Nanomaterials - Toxicity, Health and Environmental Issues", Wiley-VCH publisher, 2006	
2.2	Sabu Thomas, Merin Sara Thomas, Laly A Pothen "Nanotechnology for Environmental Remediation" Wiley-VCH publisher, 2022	
2.3	G.E. Fryxell, G.Cao, "Environmental Applications of Nanomaterials: Synthesis, Sorbents and Sensors", Imperial College Press, 2007	
2.4	Glen Fryxell, Jun Liu, Shas Mattigod, "Self-Assembled Monolayers on Mesoporous Supports (SAMMS) – an Innovative Environmental Sorbent" Materials Technology, 14,188, 1999	
3.0	**Biotoxicity of Nanoparticles in Environmental Pollution**	**18 hrs**
3.1	Introduction; Nanoparticles in the Environment; Nanoparticles in Mammalian Systems; Health Threats	
3.2	Nanomaterials and Biotoxicity; Toxicological Studies and Toxicity of CNTs-case study; Pulmonary toxicity, cytotoxicity and cardiovascular effects	
3.3	Toxicity of CNTs and metal oxides and Occupational Exposure Risk; Toxicity of MWCNTs/SWCNTs and Impact on Environmental Health	
3.4	Air Pollution; Introduction to Air Pollution Particles	
Suggested Reading Specific to the module		
3.1	Challa. S. S. R, Kumar, "Nanomaterials - Toxicity, Health and Environmental Issues", Wiley-VCH publisher, 2006	
3.2	Ying Liu, Yuliang Zhao, Baoyun Sun and Chunying Chen, "Understanding the Toxicity of Carbon Nanotubes" Accounts of Chemical Research, 46, 702, 2012	
3.3	Norihiro Kobayashi, Hiroto Izumi, and Yasuo Morimoto, "Review of toxicity	

	studies of carbon nanotubes" J.Occup.Health., 59,394,2017	
3.4	S.C. Bhatia, Textbook of Air Pollution and its Control, Atlantic Publishers and Distributors (P) Ltd, 2007	
4.0	**Nanotoxicity on human organs**	**18 hrs**
4.1	Dermal uptake of nanoparticles, Effects of Nanoparticles on the Cardiovascular System; myocardial infarction	
4.2	Nanoparticle Translocation and Direct Vascular Effects; Endothelial Dysfunction and Endogenous Fibrinolysis	
4.3	Coagulation and Thrombosis; Cardiac Autonomie Dysfunction; Effects of Nanoparticles on the Liver and Gastrointestinal Tract	
4.4	Effects of NP on the Nervous System, Blood brain barrier	
Suggested Reading Specific to the module		
4.1	Challa. S. S. R, Kumar, "Nanomaterials - Toxicity, Health and Environmental Issues", Wiley-VCH publisher, 2006	
4.2	Cristina Buzea, Ivan I. Pacheco, Kevin Robbie "Nanomaterials and nanoparticles: Sources and toxicity" Biointerphases, Vol. 2, 2007	
4.3	Challa. S. S. R, Kumar, "Nanomaterials - Toxicity, Health and Environmental Issues", Wiley-VCH publisher, 2006	
4.4	Sermin Genc, Zeynep Zadeoglulari, Stefan H. Fuss, Kursad Genc, "The Adverse Effects of Air Pollution on the Nervous System", *Journal of Toxicology*, vol. 2012, 2012	

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Challa. S. S. R, Kumar, "Nanomaterials - Toxicity, Health and Environmental Issues", Wiley-VCH publisher, 2006

2 Nancy. A, Monteiro-Riviere, Lang Tran. C, "Nanotoxicology: Characterization, Dosing and Health Effects", Informa healthcare, 2007.
3 Drobne. D, "Nanotoxicology for safe and Sustainable Nanotechnology", Dominant publisher, 2007
4 Zafar Nyamadzi. M, "A Reference handbook of nanotoxicology", Dominant publisher, 2008
5 Cristina Buzea, Ivan I. Pacheco, Kevin Robbie "Nanomaterials and nanoparticles: Sources and toxicity" Biointerphases, Vol. 2, 2007

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 T. Pradeep, "Nano: The Essentials Understanding nanoscience and nanotechnology", Tata McGrawHill Publishing Company Limited NEW DELHI, 2007.
2 Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, Publisher: CRC Press 2008

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Explain different mechanisms involved in the cellular uptake of nanoparticles.
2 Discuss the significance of protein corona in internalization of nanoparticles.
3 Classify various hybrid nanostructures for environmental remediation applications.
4 Explain the role of functionalized CNTs in controlling air pollution.
5 Discuss in detail about the occupational exposure to engineered nanomaterials.
6 Explain harmful effects of metal oxide nanoparticles on human health.

7 Compare positive and negative effects of nanoparticles on central nervous system.

8 Explain the effect of nanoparticle on heart and blood vessel.

Semester I	
Practical	
Course Code: **MSNST01DSC05**	Course Name: **Nano Lab 1**

Course Description

The course is divided into four modules. Each module discusses about the synthesis and characterization of different nanomaterials. Module one discusses about the synthesis of metal nanoparticles such as Gold, silver via chemical and green synthesis methods and its characterization. Module two discuss about the synthesis and size tuning of CdSe quantum dots and its characterization. Metal oxide nanoparticl and magnetic nanoparticle synthesis and its studies are included in module three and four of this course respectively.

Course Objectives

1 To develop practical skill on various synthesis methods of nanomaterials and their characterization.

2 Hands on experience on various analytical instruments.

3 To develop the data collection skill, to analysis and interpret the results obtained.

redit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
-	4	4	-	168	168	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Synthesize different nanomaterials using physical, chemical and biological methods.

C02	Tune the size of nanomaterials by controlling the synthesis conditions.
C03	Know about different analytical instruments and software necessary for the synthesis and characterization of the samples.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Module I**	**42 hrs**
1.1	Synthesis of different sized Ag nanoparticles by aqueous method and their optical microscopy studies	
1.2	Synthesis of different sized Au nanoparticles by aqueous method and their optical microscopy studies	
1.3	Ag-assisted Electroless etching of Si wafer to form Si nanowires	
1.4	Characterisation of Si nanowires and their application as electrodes	
2.0	**Module II**	**42 hrs**
2.1	Chemical synthesis of CdSe Quantum dots with different sizes.	
2.2	Band gap estimation of CdSe quantum dots by using optical spectroscopy	
2.3	Exciton and plasmon interaction studies of Au-CdSe system by using optical spectroscopy.	
3.0	**Module III**	**42 hrs**
3.1	Sol-gel synthesis of ZnO nanoparticles.	
3.2	Analysis of optical properties of ZnO nanoparticles	
3.3	Synthesis of activated carbon using KOH activation and controlling the pore size by varying parameters	
3.4	Study the electric double layer capacitance properties of activated carbon.	

3.5	Synthesis of 2-D nanosheets of MoS_2 by exfoliation technique
4.0	**Module IV** **42 hrs**
4.1	Coprecipitation synthesis of magnetic (iron oxide) nanoparticles.
4.2	Steric and electrostatic stabilization of iron oxide nanoparticles
4.3	Stability studies of iron oxide nanoparticle dispersions using optical microscopy

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao , Imperial college Press, (2006). Publisher: World Scientific Publishing Company; 2 edition (4 January 2011) ISBN-13: 978-9814324557

2 Nanoparticles and Nanostructured Films- Preparation Characterization and Applications by Janos H. Fendler, WILEY-VCH Verlag GmbH. D-69469 Weinheim (Federal Republic of Germany), 1998. Publisher: Wiley VCH (28 May 1998) ISBN-13: 978-3527294435

3 Nanomaterials and Nanochemistry by C. Brechignac.P. Houdy M. Lahmani, Springer-Verlag (2007). (For Unit III-Part I Chapter I)

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd. New Delhi) ISBN-13: 978-0-07-061788-9

2 Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. Publisher: CRC Press (15 December 2008) ISBN-13: 978-1420047790

TEACHING LEARNING STRATEGIES

- Practical, Viva Voce

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Semester II	
Core Course	
Course Code: **MSNST02DSC06**	Course Name: **Design and Synthesis of Nanomaterials**

Course Description

The course is divided into four modules. Each module describes a different class of Nano synthesis approach. Top-down and bottom-up approach of preparing nanomaterials are familiarized and the physical, chemical and biological approaches of nanomaterials synthesis are covered in the first second and third module respectively. Ways to tune the morphology and functional properties by tuning the preparation parameters are elaborately considered. The fourth module describes the fundamentals of different lithographic processes for the fabrication of nanodevices.

Course Objectives

1. To learn the top-down and bottom-up synthesis approach of nanomaterials.
2. To understand various physical, chemical and biological methods for the synthesis of nanomaterials.
3. To tune the morphology and functional properties of nanomaterials by tuning the reaction parameters.
4. To apply basic knowledge of synthesis to prepare functional and smart nanomaterials.
5. To understand the lithographic process for the fabrication of micro and nanodevices.

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
4	0	4	72	0	72	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Synthesize nanomaterials using physical, chemical and biological approaches.
C02	Predict the nucleation and growth mechanisms of various nanostructures.
C03	Tune the size and shape of the nanomaterials for diverse applications.
C04	Design functionalized nanoparticles for specific applications.
C05	Theoretically formulate the fabrication parameters and techniques for device manufacturing using lithographic techniques.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Physical methods for synthesis of nanomaterials**	**20**
1.1	Inert gas condensation-Principle, advantages and disadvantages, arc discharge – synthesis of CNTs and fullerenes.	
1.2	laser ablation-principle, mechanism of nanoparticle reduction, Coloumb explosion, laser pyrolysis- Principle, advantages and disadvantages, layer deposition, Spray pyrolysis	
1.3	Microwave irradiation, Gamma radiation-versatility, various kind of nanostructure synthesis, ion implantation	
1.4	Physical Vapour deposition-Principle, evaporation and sputtering, molecular beam epitaxy, chemical vapour deposition method- homogeneous and heterogeneous process, transport phenomenon, reaction kinetics, types of CVD	
1.5	ball milling-principle, grinding media, Electrospinning-processing parameters, factors affecting the process.	
Suggested Reading Specific to the module		
1.1	Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao , Imperial college Press, (2006).	
1.2	Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009.	
1.3	Angel Yanguas-Gil, Growth and Transport in Nanostructured Materials Reactive Transport in PVD, CVD, and ALD, Springer International Publishing,	

	2016	
1.4	An introduction to Electrospinning and Nanofibers by Seeram Ramakrishna, Kazutoshi Fujihara, Wee Eong Tee, Teck Cheng Lim, Zaveri Ma, World Sci. Pub. Ltd. Singapore, 2005	
2.0	**Chemical methods for synthesis of nanomaterials**	**20**
2.1	Chemical methodologies, their advantages, nanoparticles, 1D-nanostructures-Nanowires, nanotubes and nanorods; 2D-nanostructures-thin films- Crystal growth mechanisms, Nanoparticles through homogeneous & heterogenous nucleation in solution	
2.2	co-precipitation, chemical reduction, hydrothermal synthesis- isothermal and temperature gradient methods, Solvothermal synthesis, Template based synthesis, Electrochemical synthesis, Sonochemical synthesis- cavitation, Polyol method Thermal decomposition	
2.3	Sol-gel synthesis- reactions and catalysts, Pechini process, Micelles and Microemulsion assisted synthesis- principle and parameters that affect size and shape of nanostructured products,	
2.4	Self-assembly- various processes, thermodynamics of self-assembly, Langmuir Blodgett (LB) method.	
Suggested Reading Specific to the module		
2.1	Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao, Imperial college Press, (2006).	
2.2	Joop Schoonman, Philippe Knauth, Nanostructured Materials, Selected Synthesis Methods, Properties and Applications, Springer US, 2002	
2.3	• Guadalupe Valverde Aguilar, Sol-Gel Method, Design and Synthesis of New Materials with Interesting Physical, Chemical and Biological Properties, IntechOpen, 2019. • Joop Schoonman, Philippe Knauth, Nanostructured Materials, Selected Synthesis Methods, Properties and Applications, Springer US, 2002	
2.4	Himadri B. Bohidar, Kamla Rawat, Design of Nanostructures Self-Assembly of Nanomaterials, Wiley, 2017	
3.0	**Biological methods for synthesis of nanomaterials**	**20**
3.1	Use of bacteria, fungi, actinomycetes and algae for nanoparticle synthesis,	

	natural synthesis of magnetic nanoparticles using magnetotactic bacteria – magnetosomes, biomineralisation and magnetite crystal growth, role of Mm6 protein	
3.2	viruses as components for the formation of nanostructured materials – common virus types used, scaffolds, specific features of plant viruses, functionalizing scaffolds	
3.3	Nanoparticle synthesis with the help of enzymes- biocatalystic enlargement, synthesis of metal nanoparticles and nanowires, Cofactor-assisted Nanoparticle synthesis, DNA assisted synthesis of nanoparticles,	
3.4	role of plant derivatives in nanoparticle synthesis, Nanomaterial synthesis from industrial or agricultural wastes- Carbon, silica and other metal oxides as specific examples	
Suggested Reading Specific to the module		
3.1	Mohammad Azam Ansari, Suriya Rehman, Microbial Nanotechnology: Green Synthesis and Applications, Springer Nature Singapore, 2021.	
3.2	Dong-Wook Han, Jin-Woo Oh, Virus-Based Nanomaterials and Nanostructures, MDPI AG, 2020.	
3.3	Zhypargul Abdullaeva, Synthesis of Nanoparticles and Nanomaterials, Biological Approaches, Springer International Publishing, 2017	
3.4	Abdel Salam Hamdy Makhlouf, Gomaa A. M. Ali, Waste Recycling Technologies for Nanomaterials Manufacturing, Springer International Publishing, 2021.	
4.0	**Lithographic techniques for fabrication of nanomaterials**	**12**
4.1	Basics of micro and nano lithography processes, Optical Lithography- Proximity, contact and projection printing, Materials and methods, Near field Scanning Optical Lithography (NSOL)	
4.2	Electron beam lithography- Rastor scan and vector scan, Pros and cons, proximity effects, SEM based nanolithography, Focused ion beam lithography	
4.3	AFM lithography – Bias assisted and force assisted methods, Dip pen lithography- Diffusive and Liquid Inks, modifications into different probe based and probe less techniques.	
Suggested Reading Specific to the module		

4.1	Chris Mack, Fundamental Principles of Optical Lithography, The Science of Microfabrication Wiley, 2011
4.2	Ivo Utke, Phillip Russell, Stanislav Moshkalev, Nanofabrication Using Focused Ion and Electron Beams Principles and Applications, Oxford University Press, 2012
4.3	José María de Teresa, Nanofabrication, Nanolithography Techniques and Their Applications, IOP Publishing, 2020

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao , Imperial college Press, (2006). Publisher: World Scientific Publishing Company; 2 edition (4 January 2011) ISBN-13: 978-9814324557
2. An introduction to Electrospinning and Nanofibers by Seeram Ramakrishna, Kazutoshi Fujihara, Wee Eong Tee, Teck Cheng Lim, Zaveri Ma, World Sci. Pub. Ltd. Singapore, 2005. Publisher: World Scientific Publishing Co Pte Ltd (8 May 2005) ISBN-13: 978-9812564542
3. Springer Handbook of Nanotechnology - Bharat Bhusan Publisher: Springer-Verlag (15 May 2006) ISBN-13: 978-3540343660
4. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. Publisher: CRC Press (15 December 2008) ISBN-13: 978-1420047790
5. Introduction to Nanoscale Science & Technology, Di Ventra, Evoy, Heflin, Springer Science, NY, 2004. Publisher: Springer; 1 edition (30 June 2004)
6. Nanofabrication- Fundamentals and Applications, By Ampere A Tseng, Singapore 2008. Publisher: World Scientific Publishing Co Pte Ltd (18 March 2008) ISBN-13: 978-9812705426

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1. Nanoparticles and Nanostructured Films- Preparation Characterization and Applications by Janos H. Fendler, WILEY-VCH Verlag GmbH. D-69469 Weinheim (Federal Republic of Germany), 1998. Publisher: Wiley VCH (28 May 1998) ISBN-13: 978-3527294435

2. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens, Publisher: Wiley-Interscience; 1 edition (30 May 2003) Sold by: Amazon Asia-Pacific Holdings
3. Nanochemistry, G.B. Sergeev, Elsevier, 2006
4. https://nptel.ac.in/courses/118/102/118102003/
5. https://nptel.ac.in/courses/118/107/118107015/

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1. The inert gas being used in the synthesis of nanomaterials by inert gas condensation would affect the final product. Explain?
2. The selection of an optimal grinding media is highly crucial in thesynthesis of nanomaterials by ball milling. Explain?
3. Laser ablation synthesis can cause freezing" of metastable phases ofthe ablated material before the formation of the stable phases. Explain?
4. Discuss the effects of the solubility of the solute in the solvent and diffusivity ofthe solvent vapour through the precipitated layer on the spray pyrolysis process.
5. Why is heterogeneous CVD preferred over homogeneous CVD?
6. Explain diffusion-controlled vs. Reaction controlled regimes for CVD?
7. Give an account on the different collision modes in ion implantation synthesis of nanostructures
8. Discuss the advantages of microwave irradiation process for the synthesis of nanomaterials.

Semester II	
Core Course	
Course Code: **MSNST02DSC07**	Course Name: **Characterization Techniques for Nanomaterials**

Course Description
The basic principles of different characterization techniques are included in this course. The course is divided into four modules. First module consist of crystallographic characterization techniques from which a detailed information about the sample formed can be understood. The morphology and topographical information related techniques are included in module two of this course. Third module include various thermo mechanical characterization techniques. The electrochemical and magnetic studies such as cyclic voltammetry, Electrochemical impedance spectroscopy, quartz crystal microbalance and some spectroscopy techniques like Mossbauer, ESR and NMR are included in module four of this course.

Course Objectives	
1	To understand the different characterization techniques used for studying the morphology, crystallographic, thermal, mechanical and electrochemical properties of nanomaterials.
2	To understand the principle of various techniques, instrumentation and their areas of application.
3	To learn the basic concept of different spectroscopic techniques and their applications.
4	To analyse and interpret the data obtained from each technique.

Credit	Teaching Hours	Assessment

L/T	P/I	Total	L/T	P/I	Total	CE	ESE	Total
4	0	4	72	0	72	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Choose the characterization technique for studying the properties of nanomaterial on the basis of their application.
C02	Analyse the data obtained from various techniques.
C03	Understand the crystallographic information of the nanomaterial synthesized.
C04	Learn about the generation of signals and peaks in different spectroscopic techniques.
C05	Elucidate the structure of organic compounds from spectroscopic techniques.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Spectroscopic Techniques**	**18**
1.1	X-ray Spectroscopy techniques: powder XRD, small angle X-ray diffraction, grazing incidence X-ray diffraction and single crystalline X-ray diffraction, X-ray fluorescence spectroscopy, X-ray photoelectron spectroscopy.	
1.2	UV-visible spectroscopy, Beer lamberts law, woodward-fieser rule for dienes and dienones.	
1.3	FT-IR spectroscopy, Raman spectroscopy, Mutual exclusion principle.	
Suggested Reading Specific to the module		
1.1	X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials,	

	2nd Edition - Harold P. Klug, Leroy E. Alexander, Publisher: Wiley-Blackwell; 2nd Revised edition edition (1 January 1974) ISBN-13: 978-0471493693
1.2	Elementary Organic Spectroscopy, Y.R Sharma
1.3	i)Principle of Physical Chemistry, B.R Puri, L.R Sharma and Madan S Pathania ii) Fundamentals of Molecular Spectroscopy, C N Banwell.
2.0	**Microscopic Techniques** **18**
2.1	Optical microscopy, fluorescence microscopy and confocal laser scanning microscopy.
2.2	Electron Microscope: scanning electron microscopy – signal generation, interaction volume, factors affecting signal quality, charging effect, edge effect, aberrations- spherical, chromatic and astigmatism, need for vacuum in EM, sample preparation, instrumentation. Transmission electron microscopy – different imaging modes - bright, dark and SAED, instrumentation.
2.3	Scanning probe microscopy: scanning tunneling microscopy, principle-quantum tunneling, constant current mode, constant height mode, piezoelectric effect, piezoscanner and feedback loop, instrumentation, atomic force microscopy, force-distance curve, contact mode, non-contact mode, tapping mode, near field scanning optical microscopy and its modes.
Suggested Reading Specific to the module	
2.1	Nanotechnology principles and Practices, Sulabha K Kulkarani.
2.2	Introduction to Nanoscience and Nanotechnology, by K K Chattopadhyay, PHI Learning Pvt. Ltd. New Delhi 2019, ISBN-13: 978-81-203-3608-7.
2.3	Nanostructures and Nanomaterial Synthesis, Properties and Application, Guozhong Cao.

3.0	**Thermal & Mechanical methods** **18**
3.1	Thermal methods: thermogravimetric analysis, derivative thermogravimetry, differential thermal analysis, differential scanning calorimetry, combustion calorimetry, thermal diffusivity by the laser flash technique.
3.2	Simultaneous techniques including analysis for gaseous products- evolved gas detection and evolved gas analysis - FTIR-TG, FTIR-MS, FTIR-GC.
3.3	Mechanical testing- Introduction, tension testing- stress-strain curve, high strain rate testing of materials, fracture toughness testing methods, hardness testing- micro, macro, nano – brinell, Rockwell, Vickers, knoop, nanoindendation.
Suggested Reading Specific to the module	
3.1	Thermal analysis Techniques and application , N K Kaushik and S K Shukla.
3.2	Thermal analysis of polymers: Fundamentals and Application, Joseph D Menczel, R Bruce Prime.
3.3	Mechanical Behaviour and testing of materials, A K Bhargava and C P Sharma.
4.0	**Magnetic & Electrochemical methods** **18**
4.1	Mossbauer spectroscopy – Mossbauer effect, isomer shift, factors effecting isomer shift, nuclear electric quadrapole splitting, Zeeman splitting.
4.2	Electron paramagnetic resonance spectroscopy – number of signals, hyperfine splitting, ESR of transition metal complexes -zero field splitting, Kramer's degeneracy, Mc. Conell relationship.
4.3	Nuclear magnetic resonance – proton nmr, equivalent and non-equivalent protons, chemical shift, shielding and de-shielding, nuclear spin-spin coupling, fluxional behaviour, ^{13}C - number of signals,^{19}F,^{31}P-NMR.
4.4	Vibrating sample magnetometer, Magneto-optic Kerr effect. Electrochemical Techniques: Cyclic voltammetry, electrochemical impedance, scanning

	electrochemical microscopy, quartz crystal micro balance.
Suggested Reading Specific to the module	
4.1	Principle of Physical Chemistry, B.R Puri, L.R Sharma and Madan S Pathania
4.2	Principle of Physical Chemistry, B.R Puri, L.R Sharma and Madan S Pathania
4.3	Introduction to Spectroscopy, Donald L Pavia, Gary M. Lampman, George S Kriz.
4.4	An Introduction of Electrochemistry, Samuel Glasstone

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Introduction to Nanoscience and Nanotechnology, by K K Chattopadhyay, PHI Learning Pvt. Ltd. New Delhi 2019, ISBN-13: 978-81-203-3608-7.

2 Characterization of Materials Vol 1 &2, by Elton N. Kaufmann, John Wiley and Sons Publication, 2003. New Jersey.

3 Principles of instrumental analysis, Douglas A Skoog, Donald M West, Saunders College, Philadelphia. Publisher: Cengage; 6 edition (1 November 2014) ISBN-13: 978-81-315- 25579.

4 NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd. New Delhi) ISBN-13: 978-0-07-061788-9

5 X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition - Harold P. Klug, Leroy E. Alexander, Publisher: Wiley-Blackwell; 2nd Revised edition edition (1 January 1974) ISBN-13: 978-0471493693

6 Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)- David B. Williams and C. Barry Carter, Publisher: Springer; 1st ed. 1996. Corr. 6th printing edition (15 April 2005) ISBN-13: 978-0306453243

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton, Publisher: Springer; Softcover reprint of hardcover 1st ed. 2005 edition (12 October 2010) ISBN-13: 978-1441938374
2 Springer handbook of Nanotechnology ed. Bharat Bhushan (Springer), Publisher: Springer-Verlag (15 May 2006) ISBN-13: 978-3540343660

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Discuss in detail the factors that influence the image quality in scanning electron microscopy.
2 Explain bright field and dark filed image formation in TEM.
3 Write a note on nanoindendation and nanotension testing.
4 Explain the terms: isomer shift, nuclear electric quadruple splitting and Zeeman splitting.
5 Discuss the nuclear spin spin splitting in ethanol.

Semester II	
Core Course	
Course Code: **MSNST02DSC08**	Course Name: **Nano Lab II**
Course Description	
The course introduces the students with different wet chemical routs for nanomaterial	

synthesis. Exposure to various sophisticated instruments is also part of the lab program.								
Course Objectives								
1. To develop practical skill on different methods of nanomaterial synthesis. 2. Hands on experience on various analytical instruments for synthesis and application. 3. To develop the data collection skill, to analysis and interpret the results obtained.								
Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
0	4	4	0	168	168	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Formulate the conditions and requirement for the synthesis of nanosized materials.
C02	Choose different physical and chemical methods suitable for the synthesis of a particular nanomaterial.
C03	Apply analytical instruments and software necessary for the synthesis and characterization of the samples

Course outcomes based on revised Blooms taxonomy

Module	**Course Contents**	**No. of Hrs**
1.0	**Module I**	**42**
1.1	• Thin film Preparation of Metal Oxide (Spin Coating) • Cyclic Voltammetry studies of Metal oxide as thin film electrodes	
1.2	• Synthesis of metal oxide nanotubes • Photocatalytic studies of semiconductors	
1.3	• Synthesis of graphene • Application of graphene as supercapacitor electrode • Molten salt synthesis of metal oxide nanoparticles	
2.0	**Module II**	**42**
2.1	• Synthesis of nanocomposite materials	
2.2	• Effect of particle size on conductivity of a nanocomposites	

2.3	• Hydro/Solvothermal synthesis of metal oxide nanostructures of different morphology by varying parameters	
2.4	• Chemical bath deposition of thin films based on metal oxides.	
3.0	**Module III**	**42**
3.1	• Solvothermal method for ZnO • Find out the band edge in UV - Vis spectroscopy	
3.2	• Synthesis of SnO_2 nanostructures • Fabrication of gas sensor using SnO_2 nanostructure	
3.3	• TGA-DTA studies of metal oxide nanoparticles	
4.0	**Module IV**	**42**
4.1	• Co-precipitation synthesis of iron oxide nanoparticles • Synthesis of ferrofluids and their characterizations using the iron oxide nanoparticles	
4.2	• Hydrothermal synthesis of TiO_2 nanoparticles • Construction of Solar cell with TiO_2 nanoparticles	
4.3	• Synthesis of polymer nanowires using electrospinning and their characterizations • Controlling the size and morphology of nanostructures by varying parameters of eletrospinning • Synthesis of metal oxide/carbon composite nanowires using electrospinning	

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

References /compulsory readings

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao , Imperial college Press, (2006). Publisher: World Scientific Publishing Company; 2 edition (4 January 2011) ISBN-13: 978-9814324557
2. Nanoparticles and Nanostructured Films- Preparation Characterization and Applications by Janos H. Fendler, WILEY-VCH Verlag GmbH. D-69469 Weinheim (Federal Republic of Germany), 1998. Publisher: Wiley VCH (28 May 1998) ISBN-13: 978-3527294435
3. Nanomaterials and Nanochemistry by C. Brechignac.P. Houdy M. Lahmani, Springer-Verlag (2007). (For Unit III-Part I Chapter I)

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1. NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd. New Delhi) ISBN-13: 978-0-07-061788-9
2. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. Publisher: CRC Press (15 December 2008) ISBN-13: 978-1420047790

TEACHING LEARNING STRATEGIES

- Practical Examinations, Semester Viva Voce

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Semester II	
Elective Course	
Course Code: **MSNST02DSE01**	Course Name: **Elements of Physical Chemistry**
Course Description	
This course introduces students to the core area of physical chemistry, based around the themes of systems, states and processes. This course consists of the topics covered in the area of chemical thermodynamics, phase changes, surface chemistry and colloidal system.	
Course Objectives	
1 To study energy conversion in different forms and entropy of the system. 2 To understand the efficiency of a process for the transformation between energy and work.	

3	To realize that stability of different phases of materials depends on basic thermodynamic functions
4	To understand the different adsorption theories and adsorption isotherm
5	To understand various dispersion types of both the dispersed phase and the dispersion medium of colloidal system.

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Formulate the Laws of thermodynamics, heat, work, thermal efficiency and various forms of energy.
C02	Analyse phase, equilibrium, component, degree of freedom and phase rule concepts
C03	Interpret the stability regions in one component and two component systems by using phase diagrams.
C04	Compare the Langmuir, Freundlich, BET and Gibbs isotherms.
C05	Summarise the basic concepts of colloidal system and its stability.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No of hrs
1.0	**Thermodynamics**	**22hrs**
1.1	First Law of Thermodynamics-types of system- state variables-extensive and intensive properties-Processes and their types-heat, work, heat capacity of a	

	system, enthalpy of a system and internal energy-State function and Path function- Isothermal Expansion-Isothermal Compression.
1.2	Second Law of Thermodynamics – Cyclic Process-Efficiency of heat engine-Carnot Theorem-Entropy and Criterion for Equilibrium – Statistical interpretation of entropy – Boltzmann equation. Entropy changes in isothermal expansion- Entropy change during phase changes- Entropy change in different processes-Entropy of mixing.
1.3	Auxiliary Functions – Thermodynamic Relations – Variation of free energy change with temperature and pressure-Maxwell's Equations – Gibbs - Helmholtz Equation – Thermodynamics of open systems-Partial Molar Properties-Concept of chemical potential-Variation of chemical potential with temperature and pressure
1.4	Clapeyron-Clausius Equation(derivation)- Application of Clapeyron-Clausius Equation - The third law of Thermodynamics-Nernst heat theorem- First, second, and third laws of thermodynamics as applied to nanoscale systems.
Suggested Reading Specific to the module	
1.1	Principles of Thermodynamics, J.P. Ansermet and S. D. Brechet, Cambridge University Press (2019)
1.2	An Introduction to Chemical Thermodynamics, R.P Rastogi, R. R Misra, Vikas publication
1.3	Thermodynamics for Chemist, Samuel Glasttone, Affiliated East West publication
1.4	Thermodynamics, Lewis and Randall, Mc Graw Hill.
2.0	**Phase Equilibria 22hrs**
2.1	Phase equilibrium in a one– component system – Water system- Carbon Dioxide system-Sulphur system -Polymorphism.
2.2	Phase diagrams of binary Systems – Lead-Silver system- Bismuth-Cadmium System-Congruent melting point-Incongruent melting point-Criteria for Phase

	stability.
2.3	Thermodynamics and kinetics of phase transformations- Homogeneous nucleation- Heterogeneous nucleation. Physical phenomena of small systems - nano-crystals.
2.4	Macromolecules-classification of macromolecules-molecular weight determination-polydispersity index-polymerisation reactions- thermodynamics and physical properties of long chain molecules and molecular structures.
Suggested Reading Specific to the module	
2.1	Phase Equilibria, Phase Diagrams and Phase Transformations: Their Thermodynamic Basis, M. Hillert , Cambridge University Press; 2nd edition (2007).
2.2	Physical Chemistry, Daniels and Alberty, John Wiley.
2.3	Physical Chemistry, G. W. Castellan, Addison-Lesley Publishing.
2.4	Gurdeep Raj Advanced Physical Chemistry GOEL Publishing House, Meerut, 2004.
3.0	**Surface chemistry 14hrs**
3.1	Surface Chemistry: Adsorption and absorption-Physisorption and Chemisorption-Factors influencing adsorption.
3.2	Adsorption isotherms- Types of adsorption isotherms, Adsorption isobar-Adsorption isostere.
3.3	Freundlich adsorption isotherm- Langmuir adsorption theory-assumptions-Langmuir adsorption isotherm- limitations.
3.4	B.E.T. theory of multilayer adsorption- B.E.T adsorption isotherm-limitations-Gibbs adsorption isotherm- Application of adsorption.
Suggested Reading Specific to the module	

3.1	Principles of Adsorption and Adsorption Processes, D. M. Ruthven, John Wiley & Sons, (1984).
3.2	Physical Chemistry, Daniels and Alberty, John Wiley.
3.3	Puri, Sharma, Pathania, Principles of physical Chemistry, Vishal publishing company, 2013.
3.4	Physics and Chemistry of Surfaces by A.W Adamson, Wiley India Pvt Ltd; Sixth edition (2011)
4.0	**Colloids 14hrs**
4.1	Colloids: Classification of Colloids, Preparation of colloidal solutions- Dispersion methods and condensation methods- Purification of colloidal solution.
4.2	Properties of colloidal solution-optical properties-electrical properties-electrokinetic properties-Electrophoresis-Electro-osmosis.
4.3	Origin of charge-The electrical double layer-gold number-Flocculation value-Emulsion- Gels- uses of colloids.
4.4	Micelle formation- The critical micellization concentration- Factors affecting the MC-Application of colloids.
Suggested Reading Specific to the module	
4.1	Principles of Colloid and Surface Chemistry, P. C. Hiemenz, R. Rajagopalan, CRC Press; 3rd edition (1997)
4.2	Encyclopedia of Colloid and Interface Science by Tharwat Tadros (2013), Springer.
4.3	Introduction to Modern Colloid Science by Robert J. Hunter, Oxford University Press.
4.4	Physical Chemistry, R. A. Albert and R. J. Silby, Wiley Eastern

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 David V. Ragone, Thermodynamics of Materials, Volume I, J. W. Wiley 1995.
2 Thermodynamics in Materials Science, By Robert T. De Hoff, McGraw-Hill, 1993.
3 Thermodynamics and Statistical Mechanics by A N Tikhonov, Peter Theodore Landsberg
4 Physical Chemistry by P. W. Atkins, Oxford Press
5 Nanoscale Materials in Chemistry by Kenneth J. Khabhunde (ed.) Wiley Interscience

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2005.
2 Daniel V. Schroeder: An Introduction to Thermal Physics, Addison-Wesley, 2000
3 Thermodynamics and Statistical Mechanics by John M. Seddon, J. D. Gal

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Formulate the Maxwell Relationship
2 Derive Clapeyron-Clausis equation.
3 Sketch the phase diagram of a simple eutectic system.
4 Analyze the different steps of crystallization process
5 Compare different types of adsorption isotherms.
6 Sketch the adsorption isobar and isostere
7 List some of the application of colloids.
8 Differentiate between lyophilic and lyophobic colloids

Semester II	
Elective Course	
Course Code: **MSNST02DSE02**	Course Name: **Nanoscale Magnetic materials and Devices**

Course Description

This course provides fundamentals of magnetism, magnetic materials and their applications in modern device technologies. The course is divided into four modules. Module 1 discusses basic concepts of magnetism. Module 2 gives an account on the electron transport and spin relaxation in magnetic multilayers. Various fabrication and characterization techniques of nanomagnetic materials are elaborated in module 3. Module 4 discusses applications of magnetic materials in data storage.

Course Objectives

1. To study the basic concept of magnetism in solids
2. To introduce the fundamentals of Nanomagnetism
3. To understand the Fabrication and Characterization techniques of nanomagnetic materials.
4. To learn the fundamentals and device applications of magnetic materials

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the fundamentals of magnetism in solids
C02	Describe the basic concepts of nanomagnetism
C03	Explain the Fabrication and Characterization techniques of nanomagnetic materials
C04	Discuss the applications of nanomagnetism in different devices
C05	Explain the principle of different nanomagnetic devices

Course outcomes based on revised Blooms taxonomy

Module	**Course Contents**	**No. of Hrs**
1.0	**Overview of Magnetism in Solids**	**16 hrs**
1.1	Introduction: Magnetic fundamentals, Spontaneous Magnetization and Curie Temperature, Magnetic Parameters, Stoner-Wohlfarth threshold	
1.2	Antiferromagnetic materials, ferroelectric domains, phase transitions, deviations from ideal ferroelectric behavior, diffuse-phase transitions, electrostriction, and electro-optic effects in ferroelectrics	
1.3	Complex perovskites, polar nano regions, ferroelectric relaxors, order-disorder ferroelectrics	
1.4	Antiferroelectrics, Memory Fundamentals – Magnetic Storage Fundamentals	
Suggested Reading Specific to the module		
1.1	Yimei Zhu, "Modern Techniques for Characterizing Magnetic Materials", Springer, 2005	
1.2	Nicola Ann Spaldin, "Magnetic Materials: Fundamentals and Device Applications" Cambridge University Press, 2003	

1.3	Georgia C. Papaefthymiou, "Nanomagnetism An Interdisciplinary Approach",CRC Press, 2022	
1.4	Kannan M. Krishnan, "Fundamentals and Applications of Magnetic Materi-als", Oxford University Press, 2016	
2.0	**Fundamentals of Nanomagnetism**	**14 hrs**
2.1	Electron Transport in Magnetic Multi-layers, Spintronics	
2.2	Spin Polarized Electron Tunneling, Interlayer Exchange Coupling	
2.3	Spin Relaxation in Magnetic Metallic layers and Multi-layers	
2.4	Non-Equilibrium Spin Dynamics in Laterally Defined Magnetic Structures	
Suggested Reading Specific to the module		
2.1	Yimei Zhu, "Modern Techniques for Characterizing Magnetic Materials", Springer, 2005	
2.2	Nicola Ann Spaldin, "Magnetic Materials: Fundamentals and Device Applications" Cambridge University Press, 2003	
2.3	J. Anthony C. Bland, Bretislav Heinrich, "Ultrathin Magnetic Structures III Fundamentals of Nanomagnetism", Springer, 2005	
2.4	J. Anthony C. Bland, Bretislav Heinrich, "Ultrathin Magnetic Structures III Fundamentals of Nanomagnetism", Springer, 2005	
3.0	**Fabrication and Characterization of Nanomagnetic materials**	**20 hrs**
3.1	Particulate Nanomagnets, Geometrical Nanomagnets, Fabrication Techniques Scaling	
3.2	Characterization using Various Techniques, Imaging Magnetic Microspectroscopy	

3.3	Study of Ferromagnetic & and Antiferromagnetic Interfaces – Optical Imaging	
3.4	Lorentz Microscopy, Electron Holography of Magnetic Nanostructures, Magnetic Force Microscopy	
Suggested Reading Specific to the module		
3.1	Nicola Ann Spaldin, "Magnetic Materials: Fundamentals and Device Applications", Cambridge University Press, 2003	
3.2	J. Anthony C. Bland, Bretislav Heinrich, "Ultrathin Magnetic Structures III Fundamentals of Nanomagnetism", Springer, 2005	
3.3	Dr. Lamberto Duò, Dr. Marco Finazzi, Dr. Franco Ciccacci ,"Magnetic Properties of Antiferromagnetic Oxide Materials: Surfaces, Interfaces, and Thin Films", Wiley-VCH, 2010	
3.4	Hans P. Oepen and H.Hopster, "Magnetic Microscopy of Nanostructures", Springer, 2004	
4.0	**Applications and Devices**	**22 hrs**
4.1	Magnetic Data Storage :Introduction, Magnetic Media, Properties – Materials Used, Write Heads, Read Heads	
4.2	Magnetoresistance – General – in Normal Metals and in Ferromagnetic Materials	
4.3	Future of Magnetic Data Storage - Magneto-Optics and Magneto-optic recording – Kerr Effect – Faraday Effect	
4.4	Magnetic Semiconductors, Spintronics devices, noise reduction	
Suggested Reading Specific to the module		
4.1	JAC Bland and B. Heinrich, "Ultrathin Magnetic Structures III – Fundamentals of Nanomagnetism", Springer, 2004	
4.2	Nicola Ann Spaldin, "Magnetic Materials: Fundamentals and Device	

	Applications", Cambridge University Press, 2003
4.3	N. Spaldin, "Magnetic Materials: Fundamentals and Applications", Cambridge University Press, 2010
4.4	Claudia Felser, Gerhard H Fecher, "Spintronics From Materials to Devices", Springer, 2013

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

i.1 Ultrathin Magnetic Structures III – Fundamentals of Nanomagnetism JAC Bland and B. Heinrich, Springer (2004) ISBN 3540219536

i.2 Modern Techniques for Characterizing Magnetic Materials Edited by Yimei Zhu, Springer (2005) ISBN 1402080077

i.3 Magnetic Materials: Fundamentals and Device Applications Nicola Ann Spaldin, Cambridge University Press (2003) ISBN 0521016584

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

i.1 J. Anthony C. Bland, Bretislav Heinrich Ultrathin Magnetic Structures III Fundamentals of Nanomagnetism, Springer ,2005.

i.2 Magnetic Microscopy of Nanostructures Hans P. Oepen and H.Hopster, Springer (2004) ISBN 3540401865

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

i.1 Explain spontaneous magnetization in ferromagnetic materials.

i.2 Discuss electro-optic effects in ferroelectrics.

i.3 Write a note on electron transport in magnetic multilayers.

i.4 Briefly explain spin polarized electron tunneling.

i.5 List out various characterization techniques of nanomagnets.

i.6 Discuss about electron holography of magnetic nanostructures.

i.7 Distinguish between Kerr effect and Faraday effect.

i.8 Write a note on spinctronics.

Semester II	
Elective Course	
Course Code: **MSNST02DSE03**	Course Name: **Nanomaterials for Energy and Environment**
Course Description	
This course deals with the energy and environmental applications of various nanomaterials. The course is divided into four modules. First module discusses about clean energy resources with a special emphasis on solar energy and solar cells. The second module gives a detailed account on various electrochemical energy storage devices such as fuel cells, batteries and supercapacitors. Third module discusses about green nanotechnology and applications of nanomaterials for environmental remediation. Preparation and importance of various biodegradable polymers is explained in module 4.	
Course Objectives	
i.1 To understand the importance of alternative energy resources such as solar energy and hydrogen energy. i.2 To understand basic principles of different types of solar cells and their importance in	

current scenario.

i.3 To introduce hydrogen energy and various production methods and storage of hydrogen.

i.4 To make a clear idea about various components and applications of fuel cells, batteries and supercapacitors.

i.5 To understand the importance of green nanotechnology and its use in environmental remediation.

i.6 To make students aware of the applications of nanotechnology in the synthesis of biodegradable polymers.

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Apply the skills and knowledge gained through the subject to real life situations and problems related to environment.
C02	Explain the basic principles of green nanotechnology and develop methods for pollution abatement and resource management.
C03	Explain the importance of alternative energy technologies such as solar energy and hydrogen energy.
C04	Remember the principles behind each electrochemical energy storage systems.
C05	Critically evaluate the environmental threats of plastics and the importance of developing biodegradable polymers.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Nanomaterials for clean energy**	**18 hrs**
1.1	Energy and Environment, Classification of energy sources, sustainable energy production based on renewable energy sources	
1.2	Sustainability: Agriculture, Water, Energy, Nanomaterials used in agriculture, Nanomaterials used in energy and environmental applications and their properties	
1.3	Solar energy, solar cells, working principle, V-I Characteristics, dye sensitized solar cell, Electron transfer mechanism in DSSC, quantum dot sensitized solar cells, Perovskite solar cells, organic solar cells, Bulk heterojunction	
1.4	Hydrogen energy, hydrogen production by water splitting, hydrogen storage	
Suggested Reading Specific to the module		
1.1	Jingbio louise Liu, Sajid Bashir, "Advanced Nanomaterials and their applications in Renewable energy", Elsevier, 2015	
1.2	Tetsuo Soga, "Nanostructured Materials for Solar Energy Conversion", Elsevier , 2006	
1.3	Alan Fahrenbruch, Richard Bube, "Fundamentals of Solar Cells Photovoltaic Solar Energy Conversion", Elsevier ,1983	
1.4	Elias K. Stefanakos, Sesha S. Srinivasan, "Clean Energy and Fuel (Hydrogen) Storage", MDPI, 2019	
2.0	**Nanomaterials in electrochemical energy storage**	**18 hrs**
2.1	Alternative energy technologies, Electrochemical energy conversion and storage systems, Ragone plot	
2.2	Fuel cells, Types of fuel cells: Polymer electrolyte membrane fuel cells, Direct methanol fuel cells, Alkaline fuel cells, Phosphoric acid fuel cells, Molten carbonate fuel cells, Solid oxide fuel cells, thermodynamics of fuel cells,	

	electrocatalysts for anode reactions, catalysts for oxygen reduction reactions	
2.3	Batteries, Li-ion battery, Electrode materials and electrolytes in Li-ion battery, Lithium dendrite formation, Solid electrolyte interphase, Types of Li-ion incorporation in anode materials: Intercalation, alloying and conversion, Na-ion battery	
2.4	General properties of electrochemical capacitors, Supercapacitor, Electrical double layer capacitor, pseudocapacitor, Intrinsic, intercalation and extrinsic pseudocapacitors, Symmetric and asymmetric super capacitors, Li-ion based hybrid supercapacitors, Applications of electrochemical capacitor	
Suggested Reading Specific to the module		
2.1	Jingbio louise Liu, Sajid Bashir, "Advanced Nanomaterials and their applications in Renewable energy", Elsevier, 2015	
2.2	G.A. Nazri and G. Pistoia, "Lithium Batteries: Science and Technology", Kluwer Academic Publishers, Dordrecht, Netherlands, 2004	
2.3	J. Larmine and A. Dicks, "Fuel Cell System Explained," John Wiley, New York , 2000	
2.4	B. E. Conway, Electrochemical Supercapacitors, Scientific Fundamentals and Technological Applications, Springer, 1999	
3.0	**Nanomaterials for environmental remediation**	**18 hrs**
3.1	Green nanotechnology and its principles	
3.2	Nanomaterials for environmental Remediation, Photocatalysis, Solid waste removal	
3.3	Water purification using nanomaterials, desalination of water, Membrane desalination processes: Membrane distillation, reverse osmosis, forward osmosis, electrodialysis	

3.4	Porous materials to store clean energy gases, Metal organic frame works (MOFs), Storage of carbon dioxide, methane and hydrogen in MOFs	
Suggested Reading Specific to the module		
3.1	Jingbio louise Liu, Sajid Bashir, "Advanced Nanomaterials and their applications in Renewable energy", Elsevier, 2015	
3.2	Challa. S. S. R, Kumar, "Nanomaterials - Toxicity, Health and Environmental Issues", Wiley-VCH publisher, 2006	
3.3	Sabu Thomas, Merin Sara Thomas, Laly A Pothen "Nanotechnology for Environmental Remediation" Wiley-VCH publisher, 2022	
3.4	Martin Schröder, "Functional Metal-Organic Frameworks: Gas Storage, Separation and Catalysis", Springer, 2010	
4.0	**Nanomaterials for biodegradable polymers**	**18 hrs**
4.1	Introduction to commercial plastics and elastomers, thermoplastics and thermosetting plastics, Glass transition temperature	
4.2	Natural Rubber (NR), modified NR and blends-Modified NR: cyclised NR, Liquid NR, deproteinized NR, Chlorinated NR, epoxidized NR, modification by grafting	
4.3	Polyesters from microbial and plant biofactories (polylactic acid and poly hyroxyalkanoates)- Plastics from vegetable oils: triglyceride oil and derived polymers	
4.4	Structure properties and applications of Cellulose and starch-based materials - Natural fillers, fibers, classification of natural fibers, reinforcements and clay nanocomposites-morphologies of clay polymer nanocomposites, Biodegradability	
Suggested Reading Specific to the module		

4.1	Harper, Charles A., "Handbook of Plastics, Elastomers, and Composites". 4th ed., McGRAW-HILL, 2002
4.2	Ghosh, Premamoy., Polymer Science and Technology: Plastics, Rubbers, Blends and Composites. 3rd ed. New York: McGraw-Hill Education, 2011
4.3	Lee, G.N., Na, J. Future of microbial polyesters. *Microb Cell Fact* **12**, 54, 2013
4.4	Khouloud Jlassi, Mohamed M. Chehimi, Sabu Thomas, "Clay-Polymer Nanocomposites", Elsavier, 2017

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

i.1 Jingbio louise Liu, Sajid Bashir, "Advanced Nanomaterials and their applications in Renewable energy", Elsevier, 2015

i.2 Tetsuo Soga, "Nanostructured Materials for Solar Energy Conversion", Elsevier , 2006

i.3 A. Nazri and G. Pistoia, "Lithium Batteries: Science and Technology", Kluwer Academic Publishers, Dordrecht, Netherlands, 2004.

i.4 J. Larmine and A. Dicks, "Fuel Cell System Explained", John Wiley, New York , 2000

i.5 Lee, G.N., Na, J. "Future of microbial polyesters" *Microb Cell Fact* **12**, 54, 2013

i.6 Khouloud Jlassi, Mohamed M. Chehimi, Sabu Thomas, "Clay-Polymer Nanocomposites", Elsavier, 2017

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

2 Francois B´eguin and El˙zbieta Frackowiak, "Supercapacitors", Wiley-VCH, 2013.

3 Yogita Bhoj, Gaurav Pandey, Anjali Bhoj, Maithri Tharmavaram, Deepak Rawtani, "Recent advancements in practices related to desalination by means of nanotechnology" Chemical Physics Impact 2,100025, 2021

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

i.1 Summarize the application of nanomaterials for energy and environment.

i.2 Explain in detail the application of nanomaterials for various components in a Dye Sensitized Solar cell.

i.3 Explain the basic electrochemistry of a Proton Exchange Membrane Fuel Cell.

i.4 Briefly explain the electrode processes in Li ion batteries.

i.5 List the advantages of functionalized CNTs in environmental applications.

i.6 Explain various methods of hydrogen production and storage.

i.7 Write a note on biodegradable polymers.

i.8 Discuss the synthesis of polymers from Triacylglycerol Oils.

Semester II	
Elective Course	
Course Code: **MSNST02DSE04**	Course Name: **Nanomaterials in Everyday life**
Course Description	
The course introduces students to the application areas of nanomaterials in day to day life. Principles and properties of specific nanomaterials advantageous for particular applications are also covered. Detailed sections are included for application areas like food, drugs, agriculture, cosmetics, textile, paint and coating etc.	
Course Objectives	
1. To learn the basic concepts of nanomaterials that can be explored for every day applications 2. To study the properties of nanomaterials to develop the knowledge on food and agricultural	

applications of nanomaterials

3. To understand the idea of nanoengineered textiles and nanomaterial based cosmetics.

4. To impart theoretical knowledge on nanostructured coatings

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the most common applications of nanomaterials
C02	Analyze the properties of nanomaterials for specific applications
C03	Explain the concept of nano-based food and food supplements
C04	Explain the principle and fabrication of nanostructured coaings
C05	Design nanomaterials for particular applications by optimising the materials and their size, shape, surface area etc

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Use of nanotechnology by the food and pharmaceuticals**	
1.1	Food Ingredients for Colour, Materials for Texture and Flavour-mechanism;	
1.2	Food production and packaging- materials, Engineered water nanostrutures, advantages, challenges	
1.3	Nutrients and dietary supplements; Food safety; Food Nanosensors;	

1.4	Nanomaterials in oral tablets- Nanocomposites- polymers-inorganics.	
Suggested Reading Specific to the module		
1.1	Food nanotechnology: proposed uses, safety concerns and regulations. Agro. Food Ind. Hitech. 27, 36–39.	
1.2	Bradley, E. L., Castle, L., and Chaudhry, Q. (2011). Applications of nanomaterials in food packaging with a consideration of opportunities for developing countries. Trends Food Sci. Technol. 22, 603–610.	
1.3	Bouwmeester, H., Dekkers, S., Noordam, M. Y., Hagens, W. I., Bulder, A. S., Heer, C., et al. (2009). Review of health safety aspects of nanotechnologies in food production. Reg. Toxicol. Pharmacol. 53, 52–62.	
1.4	Application of polymer nanocomposite materials in food packaging. Croat. J. Food Sci. Technol. 7, 86–94	
2.0	**Nanotechnology in Agriculture**	**20**
2.1	Nanomaterials in Plant germination; Effects of the types, properties, and concentrations of nanomaterials on plant growth, seed germination and root and shoot growth	
2.2	Properties of nanomaterials on various abiotic (salinity, drought, heat, high light, and heavy metals) and biotic (pathogens and herbivores) stresses;	
2.3	Pesticides and fertilizers-control of plant pests-insecticidal potential of nanomaterials-Antimicrobial activity-Antifungal activity-Nanomaterials to control plant viruses;	
2.4	Nanomaterials for plant pathogen detection; Pesticide residue detection	
Suggested Reading Specific to the module		
2.1	Jennifer Kuzma and Peter Ver Hage, “Nanotechnology in agriculture and food production”, Woodrow Wilson International Center, 2006.	
2.2	Lynn. J, Frewer, Willehm Norde. R. H, Fischer and Kampers. W. H “Nanotechnology in the Agri- food sector”, Wiley-VCH Verlag, 2011.	
2.3	Nanotechnology in agriculture: Prospects and constraints. Nanotechnology, Science	

	and Applications. 2014;7:63-71
2.4	Applications of Nanotechnology in Agriculture in Applications of Nanobiotechnology Edited by Margarita Stoytcheva and Roumen Zlatev, Intechopen.
3.0	**Nanotechnology in Cosmetics and Textiles**
3.1	Nano-variegation in cosmetics; Mineral-based cosmetic ingredients with nano-sized dimensions;
3.2	Nano-sized materials employed in cosmetics- fullerenes, nanotubes, liposomes, quantum dots, dendrimers, metal nanostructures, hydrogels;
3.3	Factors affecting the efficiency of nanostructures in cosmetics-size, shape, surface area;
3.4	Nano-engineered textiles- Properties: water and oil repellence- wrinkle resistance-anti microbial properties-UV blocking-Strength enhancement; Electronic and photonic technologies in textiles;
3.5	Nano-engineered textiles for diverse application fields like in space, defense, medicine etc; Future Directions.
Suggested Reading Specific to the module	
3.1	Mark. A, Ratner and Daniel Ratner, "Nanotechnology: A Gentle Introduction to the Next Big Idea", Pearson, 2003.
3.2	Morales ME, Gallardo V, Clarés B, García MB, Ruiz MA. Study and description of hydrogels and organogels as vehicles for cosmetic active ingredients. J Cosmet Sci. 2009;60:627–36.
3.3	Fytianos, G., Rahdar, A., & Kyzas, G. Z. (2020). Nanomaterials in cosmetics: Recent updates. Nanomaterials, 10(5), 979.
3.4	Brown. P. J and Stevens. K "Nanofibers and Nanotechnology in Textiles", Woodhead Publishing Limited, Cambridge, 2007.
3.5	Brown. P. J and Stevens. K "Nanofibers and Nanotechnology in Textiles", Woodhead Publishing Limited, Cambridge, 2007.

4.0	**Nanomaterials in paints and coatings**	
4.1	Nanomaterials in Paints; Materials and methods- Different metal oxides in use.	
4.2	Advantages of Nanopaints - anti microbial properties-dust repellence- corrosion repellence	
4.3	Components: Pigment, thinner, binder and filler, Additives; Introduction to colour-changing paints	
4.4	Release behaviour and life cycle of nanopaints; Potential environmental benefits of nanomaterials in coating	
Suggested Reading Specific to the module		
4.1	Kaiser, Jean-Pierre, Stefano Zuin, and Peter Wick. "Is nanotechnology revolutionizing the paint and lacquer industry? A critical opinion." Science of the Total Environment 442 (2013): 282-289.	
4.2	Zhdanok, S. A., et al. "Influence of carbon nanomaterials on the properties of paint coatings." Journal of Engineering Physics and Thermophysics 84.6 (2011): 1242-1247.	
4.3	Zhdanok, S. A., et al. "Influence of carbon nanomaterials on the properties of paint coatings." Journal of Engineering Physics and Thermophysics 84.6 (2011): 1242-1247.	
4.4	Gottschalk, Fadri, and Bernd Nowack. "The release of engineered nanomaterials to the environment." Journal of environmental monitoring 13.5 (2011): 1145-1155.	

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1. Mark. A, Ratner and Daniel Ratner, “Nanotechnology: A Gentle Introduction to the Next Big Idea”, Pearson, 2003.
2. Jennifer Kuzma and Peter Ver Hage, “Nanotechnology in agriculture and food production”, Woodrow Wilson International Center, 2006.
3. Lynn. J, Frewer, Willehm Norde. R. H, Fischer and Kampers. W. H “Nanotechnology in the Agri- food sector”, Wiley-VCH Verlag, 2011.
4. Brown. P. J and Stevens. K “Nanofibers and Nanotechnology in Textiles”, Woodhead Publishing Limited, Cambridge, 2007.

5. Fytianos, G., Rahdar, A., & Kyzas, G. Z. (2020). Nanomaterials in cosmetics: Recent updates. Nanomaterials, 10(5), 979.

6. Kaiser, Jean-Pierre, Stefano Zuin, and Peter Wick. "Is nanotechnology revolutionizing the paint and lacquer industry? A critical opinion." Science of the Total Environment 442 (2013): 282-289.

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Applications of Nanotechnology in Agriculture in Applications of Nanobiotechnology Edited by Margarita Stoytcheva and Roumen Zlatev, Intechopen.

2 Chang. W.N "Nanofibres fabrication, performance and applications", Nova Science Publishers Inc, 2009.

3 Zhdanok, S. A., et al. "Influence of carbon nanomaterials on the properties of paint coatings." Journal of Engineering Physics and Thermophysics 84.6 (2011): 1242-1247.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1. Write a note on the applications of nanomaterials in food packaging?

2. How can you improve the bioavailability in oral drug delivery?

3. What are the factors that affect the efficiency of nanomaterials used in cosmetics?

4. What are the different properties that can be imparted to nano-engineered fabrics?

5. Give a note on different metal oxide nanostructures used in nanomaterial based paints?

Semester II	
Elective course	
Course Code: **MSNST02DSE05**	Course Name: **Polymer Science**

Course Description

This course deals with the basics related to the chemistry of polymers. The course is divided into four modules. The first modules discuss about the introduction to polymers, its classification and some of the commercially important polymers, its synthesis and properties. The final part of this module deals with different inorganic polymers, their properties and application. The second module deals with the physical properties of polymers. Details regarding some of the special polymers are mentioned in module three. Fourth module deals with the formation of polymer nanocomposites, different filler used, and their properties.

Course Objectives

1. To understand about the classification of polymers.
2. To familiarize the students with the significance and determination of their molecular mass
3. To understand in detail the reaction mechanisms involved in the formation of polymers.
4. To acquire awareness on the introducing compatible nanofillers in the formation of polymer nanocomposites.

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

COURSE OUTCOMES

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Identify and select a polymer for a particular application on the basis of their properties.
C02	Interpret the properties of polymer nanocomposites upon adding various fillers.
C03	Explain various applications of filler incorporated polymer nanocomposites.
C04	To acquire knowledge about special polymer materials in various field.

Module	**Course Contents**	**14 Hrs**
1.0	**Introduction to Polymers**	
1.1	Introduction to polymer chemistry. Monomers, polymers, repeating units, functionality. Nomenclature of polymers.	
1.2	Classification - natural and synthetic, methods of polymerization (addition and condensation), copolymerization. Some importance polymers; natural and synthetic like polythene, nylon, polyesters, bakelite, rubber.	
1.3	Inorganic polymers- importance, advantages and applications- structure, preparation and properties of silicones and polyphosphazenes.	
Suggested Reading Specific to the module		
1.1	Malcon P. Steves, Polymer chemistry-An introduction, 3rd edition, Oxford University Press.	
1.2	F. W. Billmayer, Text book of Polymer Science, 3rd edition, John Wiley &Sons	
1.3	V. R. Gowariker, N. V. Viswanathan&J. Sreedhar, Polymer Science, New Age International Publishers.	
2.0	**Molecular mass and size of polymers**	
2.1	Degree of polymerization and molecular weight. Practical significance of molecular weight. Threshold molecular weight. Concept of average molecular mass and molecular mass distribution.	

2.2	Number average, weight average and z average molecular mass and their calculation. Viscosity average molecular mass. Molecular mass distribution curve. Polydispersity and polydispersity index of polymers.
2.3	Examples of monodispersed and polydispersed polymers. Molecular mass & mechanical properties. Size of polymer molecules.
Suggested Reading Specific to the module	
2.1	V. R. Gowariker, N. V. Viswanathan&J. Sreedhar, Polymer Science, New Age International Publishers.
2.2	P. Bahadur & N. V. Sastry, Principles of Polymer Science, Narrora Publishing House, 2nd Edition, New Delhi.
2.3	Premamoy Ghosh, Polymer Science & Technology, 3rd edition, Tata McGraw Hill Education Pvt. Ltd., New Delhi.
3.0	**Special Polymers**
3.1	Fire retardant polymers, mechanism of fire retardency, fire retardants: halogen based, nitrogen based, phosphorous based, nanoparticles
3.2	Liquid crystalline polymers: properties, types and application
3.3	Biodegradable polymers, high temperature polymers: properties, types and application.
Suggested Reading Specific to the module	
3.1	D. Feldman and A. Barbalata, Synthetic Polymers, Chapmann and Hall.
3.2	Premamoy Ghosh, Polymer Science & Technology, 3rd edition, Tata McGraw Hill Education Pvt. Ltd., New Delhi.
3.3	G. Odian, Principles of polymerization, 3 rd edition, John Wiley &Sons.
4.0	**Polymer Nanocomposites**
4.1	Polymer nanocomposites: phase separated, intercalated, exfoliated.

4.2	Nanofillers: Carbon based-CNT and Graphene, layerd nanoclays, porous and hollow nanoparticles – halloysite, zeolite, Nanocellulose, metallic alloys, compatibilization of polymer nanocomposites,
4.3	Processing of polymer nanocomposites – insitu, blending, properties and application.
Suggested Reading Specific to the module	
4.1	G. S. Misra, Introductory Polymer Chemistry New age International Publishers & Distributors, New Delhi
4.2	V. K. Ahluwalia& A. Misra, Polymer Science-A Text Book, AneBooks, India, New Delhi.
4.3	J. R. Fried, Polymer Science & Technology, Prentice Hall of India Pvt. Ltd, New Delhi.
4.4	V. R. Gowariker, N. V. Viswanathan&J. Sreedhar, Polymer Science, New Age International Publishers.

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Malcon P. Steves, Polymer chemistry-An introduction, 3rd edition, Oxford University Press.
2 F. W. Billmayer, Text book of Polymer Science, 3rd edition, John Wiley &Sons
3 V. R. Gowariker, N. V. Viswanathan&J. Sreedhar, Polymer Science, New Age International Publishers.
4 P. Bahadur & N. V. Sastry, Principles of Polymer Science, Narrora Publishing House, 2nd Edition, New Delhi.
5 Premamoy Ghosh, Polymer Science & Technology, 3rd edition, Tata McGraw Hill Education Pvt. Ltd., New Delhi.
6 G. Odian, Principles of polymerization, 3 rd edition, John Wiley &Sons.

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 G. S. Misra, Introductory Polymer Chemistry New age International Publishers & Distributors, New Delhi

2 V. K. Ahluwalia& A. Misra, Polymer Science-A Text Book, AneBooks, India, New Delhi.

3 J. R. Fried, Polymer Science & Technology, Prentice Hall of India Pvt. Ltd, New Delhi.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Discuss in detail about the filler materials used in the formation of polymer nanocomposites.
2 Explain the mechanism of fire retardant polymers.
3 Write a note on classification of polymers.
4 Explain the terms: polydispersive index, number average molecular mass, mass average molecular mass.
5 Discuss the classification and properties of polyphosphazenes.

Semester II	
Elective Course	
Course Code: **MSNST02DSE06**	Course Name: **Nanopharmaceuticals**
Course Description	
The course introduces students to the application areas of nanomaterials in drugs and pharmaceuticals. Principles and properties of specific nanomaterials advantageous for	

pharmaceutical applications are also covered. Basic understanding of molecular cell biology required for the development of nanostructured pharmaceuticals are included.

Course Objectives

1. To learn the role of nanomaterials in Pharmaceutical industry
2. To study the properties of different nanomaterials depending upon their application as medicine
3. To develop knowledge on molecular cell biology
4. To understand the idea of nanostrctured diagnostic tools.

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the most common applications of nanomaterials in pharmaceuical industry
C02	Analyze the properties of nanomaterials for medicinal and diagnostic applications
C03	List the criteria for selection of nanostructures as drugs
C04	Explain the clinical translatability of drugs

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Introduction to Nanophrmaceuticals**	**13**
1.1	Nanotechnology in pharmaceutical industry: Nano particle based drug delivery systems, Regenerative medicine, nano-immuno conjugates,	
1.2	Bio-availability and delivery of nutraceuticals and functional foods using nanotechnology,	
1.3	Tissue engineering/regenerative medicine, Nano-robotics in surgery, Nano-tools for early detection diseases, Nano-medicine for cancer treatment, smart delivery system	
1.4	Guidelines for Evaluation of Nanopharmaceuticals in India	
Suggested Reading Specific to the module		

1.1	1. Nanopharmaceuticals: Principles and Applications, 3 volumes Editors: Vinod Kumar Yata, Shivendu Ranjan, Nandita Dasgupta, Eric Lichtfouse, Springer, 2. Nanopharmaceuticals in Regenerative Medicine, Ed. Durgesh Nandini Chauhan Harishkumar Madhyastha, CRC	
1.2	Nanopharmaceuticals in Regenerative Medicine, Ed. Durgesh Nandini Chauhan Harishkumar Madhyastha, CRC	
1.3	Biopharmaceuticals: Biochemistry and Biotechnology by Gary Walsh Wiley-Blackwell; 2nd edition (2003)	
1.4	https://pib.gov.in/PressReleseDetail.aspx?PRID=1589101	
2.0	**Essential Molecular Cell biology**	**14**
2.1	Molecular Cell Biology: Cell- Structure & Function of Cell Membrane, Different cell types and their Functions, Sub-cellular Organelles and their Functions	
2.2	Nucleotide- Structure and Functions of DNA & RNA. Biologically important nucleotide, protein synthesis, unnatural amino acid	
2.3	Mechanistic understanding of various diseases and target identification for early detection	
Suggested Reading Specific to the module		
2.1	Nelson, D. L., Cox, M. M. and Lehninger, A. L. (2009) Principles of Biochemistry. IV Edition. W.H. Freeman and Co.	
2.2	Murray, R. K., Granner, D. K., Mayes, P. A. and Rodwell, V.W. (2009) Harper's Illustrated Biochemistry. XXVIII edition. Lange Medical Books/ McGraw-Hill.	
2.3	Nanomaterials-Synthesis, Properties and Applications by A.S. Edelstein and R.C Cammarata, Institute of Physics Publishing.	
3.0	**Nanotechnology -based approaches in nanopharmaceuticals**	**14**
3.1	Nanopharmaceuticals in clinical translatability, Target Identification and Drug designing: High-Throughput Screenings	
3.2	Affinity matrix approaches: On-bead affinity matrix, Biotin tags in affinity matrix, Fluorescent tags in affinity matrix, Photo-affinity tags in affinity matrix.	
3.3	Drug western approaches, Three-hybrid system approaches: mRNA display	

	approaches, Protein micro-array approaches, Drug affinity responsive target stability	
Suggested Reading Specific to the module		
3.1	Nanoparticulates as Drug Carriers Edited by Vladimir P.Torchilin, Imperial College Press, (2006)	
3.2	Medical Nanotechnology in Nanomedicine, Harry F. Tibbals · 2017	
3.3	Drug target selection and validation, Marcus T. Scotti, Carolina L. Bellera, Springer International Publishing, 2022	
4.0	**Targeted drug delivery**	**13**
4.1	Multi-targeted drugs – delivery of nucleic acids- barriers to therapeutic applications –interaction of organic molecules of the drug with pathological tissue	
4.2	Ligand targeted nanoparticles drug delivery: combining multiple functions - formation of nucleic acid core particle – protective steric coating	
4.3	Surface exposed ligands targeting specific tissues	
Suggested Reading Specific to the module		
4.1	Surface Modification of Nanoparticles for Targeted Drug Delivery, Springer International Publishing ,Yashwant V Pathak · 2019	
4.2	Surface Modification of Nanoparticles for Targeted Drug Delivery, Springer International Publishing ,Yashwant V Pathak · 2019	
4.3	Targeted Drug Delivery : Concepts and Design, Springer International Publishing, Padma V. Devarajan, Sanyog Jain · 2014	

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Nanopharmaceuticals: Principles and Applications, 3 volumes Editors: Vinod Kumar Yata, Shivendu Ranjan, Nandita Dasgupta, Eric Lichtfouse, Springer,

2 Nanopharmaceuticals in Regenerative Medicine, Ed. Durgesh Nandini Chauhan Harishkumar Madhyastha, CRC

3 Biopharmaceuticals: Biochemistry and Biotechnology by Gary Walsh Wiley-Blackwell; 2nd edition (2003)

4 Surface Modification of Nanoparticles for Targeted Drug Delivery, Springer

International Publishing ,Yashwant V Pathak · 2019

5 Targeted Drug Delivery : Concepts and Design, Springer International Publishing, Padma V. Devarajan, Sanyog Jain · 2014

6 Murray, R. K., Granner, D. K., Mayes, P. A. and Rodwell, V.W. (2009) Harper's Illustrated Biochemistry. XXVIII edition. Lange Medical Books/ McGraw-Hill.

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Molecular Biology of the Cell, Garland publications, Bruce Alberts · 2004

2 Basic Fundamentals of Drug Delivery, Elsevier Science, Rakesh Kumar Tekade, 2018

3 Exploring the Potential of Nanopharmaceuticals: Extending our Focus Beyond Conventional Drugs, Frontiers Media SA, Alam Zeb, Amirali Popat, Faisal Raza, Hussain Ali, Saeed Ahmad Khan, 2022

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1. Write a note on the applications of nanomaterials in neutaceuticals and functional foods?
2. How can you improve the bioavailability of drugs in nanostructured drugs?
3. Give a detailed account on various affinity matrix approaches in drug delivery?
4. What are the different hybrid system approaches in drug delivery?
5. Give a note on mRNA display approaches?

Interdisciplinary/ Multi-disciplinary Course	
Course Code: **MSNST02IDC01**	Course Name: **Composite Materials**

Course Description

This is an interdisciplinary course, designed to build a basic knowledge of composite materials, which integrates the principles of chemistry, biology and nanoscience. It provides a clear idea about different types of composites, and their classification based on the constituent materials. Furthermore, the study extends to recent developments in composites which include the applications of various nanocomposites in different areas.

Course Objectives

1. To introduce students the basic concepts of nanocomposites, their classification based on matrix and reinforcement materials and their applications in different areas.
2. To make students aware of recent developments and utilization of different nanocomposites in various fields such as aerospace, dentistry, energy storage etc.
3. To train the students about the role and selection of different reinforcement materials for designing composites with desired properties.
4. To understand various nanocomposite processing methods.

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
2	-	2	30	-	30	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the basic concepts of composites and their components.

C02	Classify composites based on the matrix and reinforcement materials used.
C03	Design nanocomposites for desired applications by proper selection of matrix and reinforcements.
C04	Analyze different properties of composites in comparison with standard materials.
C05	List out recent developments and applications of composite materials in different areas.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of hrs
1.0	**Introduction to Composite Materials**	**15**
1.1	Introduction to composite materials, Classification based on Matrix Material -Polymer matrix composites (PMC), Metal matrix composites (MMC), Ceramic matrix composites (CMC)	
1.2	Reinforcement Materials: Metallic, Polymer, Ceramic and Composite fibres, Whiskers and Particulates, Nano-fillers used in polymer composites, Reinforcement fibres, Woven fabrics and non-woven random mats.	
1.3	Properties of composites in comparison with standard materials, Applications of metal, ceramic and polymer matrix composites.	
1.4	Recent developments in Composites: Self-healing composites, antimicrobial composites, stimuli response composites, self-adhesive composites, Micro and Nanocomposites, Biocomposites and Carbon / carbon composites (Advantages and limitations of carbon matrix).	
	Suggested Reading Specific to the module	
1.1	Mathews F.L. and Rawlings R.D., Composite materials: Engineering and Science, Chapman and Hall, London, England, 1st edition, 1994.	
1.2	Sharma S.C., Composite materials, Narosa Publications, 2000	
1.3	Mallick, P.K, Composite Materials Technology: Process and Properties, Hanser, New York, 1990.	

1.4	Yongjing Wang, Duc Truong Pham & Chunqian Ji | Eileen Harkin-Jones (Reviewing Editor) (2015) Self-healing composites: A review, Cogent Engineering, 2:1	
2.0	**Nanocomposites: Properties and Applications**	**15**
2.1	Definition of nanocomposites, b**asic Constituent materials in Nanocomposites**	
2.2	Role and Selection of reinforcement materials, Glass fibers, Carbon fibers, Boron Fibers, Natural fibers, Multiphase fibers, Aramid fibers.	
2.3	Particle reinforced composites, fiber reinforced composites, Core-Shell nanocomposites. **Nanocomposite Processing Methods**: In-situ polymerization technique, Solution casting, Electro spinning, melt mixing. Properties of nanocomposites: Mechanical, electrical, thermal and barrier properties	
2.4	Applications of nanocomposites in Aerospace, Coating, Hybrid Nanocomposite materials for food packaging, graphene-carbon nanotube nanocomposite for energy storage applications, Nanocomposites for solar cells, nanocomposite materials for Lithium-ion battery.	
Suggested Reading Specific to the module		
2.1	Lubin - Handbook of composites – (Van Nostrand, 1982)	
2.2	Composite Polymeric Materials. R.P. Sheldon. Applied Science Publishers, London. 1982	
2.3	Singh, N.B. (Ed.). (2022). Nanocomposites (1st ed.). Jenny Stanford Publishing. https://doi.org/10.1201/9781003314479	
2.4	Jayatissa, A. (Ed.). (2022). Applications of Nanocomposites (1st ed.). CRC Press. https://doi.org/10.1201/9781003247074	

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Ajayan PM, Schadler LS, Braun PV. Nanocomposite science and technology. Weinheim: WILEY-VCH Verlag GmbH & Co. KGaA; 2003.

2 Introduction to Nano Technology by Charles. P. Poole Jr and Frank J. Owens; Wiley India Pvt. Ltd., 2003

3 HS Nalwa, American Scientific Publishers, Los Angeles, CA, 2004

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Gowariker and Viswanathan, Polymer Science, Wiley Eastern, 1986

2 Bill Meyer, A Text Book of Polymer Chemistry, John Wiley & Sons, Singapore, 1994.

3 Yiu-Wing Mai and Zhong –Zhen Yu, Polymer-Nanocomposites, CRC Press, 2006.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Write a note on the classification of nanocomposites.

2 Explain general characteristics of nanocomposites.

3 Explain recent developments and potential applications of nanocomposites.

4 Write a note on the role and selection of reinforcement materials in the preparation of composite materials with desired properties.

5

Interdisciplinary/Multidisciplinary Course II	
Course Code: **MSNST02IDC02**	Course Name: **Nanobiomaterials**
Course Description	
This course provides basic overview of nanobiomaterials and their applications. This course begins with a review of various types of nanobiomaterials. Subsequently the course covers processing	

methods of nanobiomaterials. Finally, application of nanobiomaterials in bio-medical fields is discussed.
Course Objectives
1 To explain the vital role of nanobiomaterials in biomedical field. 2 To provide an overview of nature and properties of nanobiomaterials 3 To explore the different processing methods of nanobiomaterials. 4 To get an idea of the different types of nanobiomaterials based on structure and properties. 5 To understand the recent trends and application of nanobiomaterials.

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
2	0	2	30	0	30	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Demonstrate the role of nanobiomaterials in biomedical field.
C02	Design different processing methods to engineer nanobiomaterials.
C03	Compare different types of nanobiomaterials based on structure and properties.
C04	Discuss the applications of nanobiomaterials in various medical field.
C05	Perform a critical analysis on the current research areas in nanobiomaterials.

Course outcomes based on revised Blooms taxonomy

Module	**Course Contents**	**No of hrs**
1.0	**Overview of Biomaterials**	**15**

1.1	Introduction- Biomaterials: -Impact of Biomaterials-Characteristics of Biomaterials-Classification of Biomaterials-Metallic Biomaterials- Ceramic Biomaterials-Polymeric Biomaterials-Composite Biomaterials.	
1.2	Nanobiomaterials: A New Generation Biomaterial-Processing of Nanobiomaterials-Sol-gel Processing-Tissue Engineering Approach.	
1.3	Nanostructured Metallic Implants- Nanostructured Bio-ceramics-Polymeric Nanobiomaterials	
1.4	Evolution of Nanocomposite Biomaterials-Nanocomposites: A New Class of Nanobiomaterials- Conventional Nanocomposites-Tissue-Engineered Nanocomposites.	
Suggested Reading Specific to the module		
1.1	Nanobiomaterials: Classification, Fabrication and Biomedical Applications Editor(s):X. W., M. Ramalingam, X. Kong, L. Zhao, (2018), Wiley-VCH	
1.2	Nanobiomaterials: State of the Art by J, Wang, H. Li, L. Tian, S. Ramakrishna (2011) , Wiley-VCH	
1.3	Biomaterials-A nano approach by S. Ramakrishna, M. Ramalingam, T.S. Sampath Kumar, W.O Soboyejo, (2010), CRC Press	
1.4	Biomaterials-A nano approach by S. Ramakrishna, M. Ramalingam, T.S. Sampath Kumar, W.O Soboyejo, (2010), CRC Press	
2.0	**Applications of nanobiomaterials.**	**15**
2.1	Biomedical Applications of Polymer Nanofibers-Dental Restoration-Wound Dressing- Drug Delivery-Tissue Scaffolds	
2.2	Biomedical Applications of Composite Biomaterials-Bone Fracture Repair-Joint Replacements-Dental Applications	
2.3	Nanobiomaterials for Tissue Regeneration-Nanobiomaterials: A New Generation Scaffolding Material. Characteristics of a Scaffold.	
2.4	Types of Scaffolding Materials- Ceramic Nanobiomaterials- Polymeric	

	Nanobiomaterials
Suggested Reading Specific to the module	
2.1	Nanobiomaterials: Classification, Fabrication and Biomedical Applications Editor(s):X. W., M. Ramalingam, X. Kong, L. Zhao, (2018), Wiley-VCH
2.2	Nanobiomaterials: State of the Art by J, Wang, H. Li, L. Tian, S. Ramakrishna (2011), Wiley-VCH
2.3	Biomaterials-A nano approach by S. Ramakrishna, M. Ramalingam, T.S. Sampath Kumar, W.O Soboyejo, (2010), CRC Press
2.4	Biomaterials-A nano approach by S. Ramakrishna, M. Ramalingam, T.S. Sampath Kumar, W.O Soboyejo, (2010), CRC Press

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Nanobiomaterials: Classification, Fabrication and Biomedical Applications
Editor(s):X. W., M. Ramalingam, X. Kong, L. Zhao, (2018), Wiley-VCH
2 Nanobiomaterials: State of the Art by J, Wang, H. Li, L. Tian, S. Ramakrishna (2011), Wiley-VCH
3 Biomaterials-A nano approach by S. Ramakrishna, M. Ramalingam, T.S. Sampath Kumar, W.O Soboyejo, (2010), CRC Press

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Nanobiomaterials: Nanostructured Materials for Biomedical Applications, Edited by Roger Narayan,Woodhead Publishing(2017)
2 Nanobiomaterials Science, Development and Evaluation Editors-in-Chief: Mehdi Razavi and Avnesh Thakor (2017)
3 Fundamentals of Biomaterials by V. Hasirci, N. Hasirci, Springer (2018)

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Discuss the characteristics of a biomaterial with examples
2 Classify various types of biomaterials with suitable examples.
3 Compare the properties of biomaterial and nanobiomaterial.
4 Explain the concept of tissue engineering and describe its key applications in human systems
5 Describe the impacts of nanobiomaterials over conventional biomaterials

Interdisciplinary /Multidisciplinary Course III	
Course Code: **MSNST02IDC03**	Course Name: **Nanotechnology and Waste Management**
Course Description	
The primary goal of the course is to increase student awareness of how nanomaterials interact in natural environments. This course will discuss the opportunities for nanotechnology to improve our quality of life, as well as the potential benefits of nanomaterials/nanotechnology for environmental applications. This course also deals with both the environmental and toxicological hazards associated with nanomaterials/nanotechnology and its waste management.	
Course Objectives	
1.To explain the vital role of nanomaterials in environmental science. 2. To provide an overview of properties of nanomaterials in waste management 3. To explore the different methods of water treatment using nanomaterials. 4. To get an idea of the nanomaterial's safety management. 5. To understand the recent trends and application of nanomaterials in waste management and	

reducing pollution.								
Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
2	0	2	30	0	30	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Describe the basic concepts of waste management
C02	Evaluate the nanomaterial toxicity and ecological effects in natural environments.
C03	Analyze the methods to improve the environment through direct application of nanomaterials for detecting, preventing, and removing pollutants
C04	Discuss the near term and future applications of nanomaterials in waste management
C05	Design different methods in waste management, controlling and reducing air pollution, water treatment, and nanomaterials safety.

Course outcomes based on revised Blooms taxonomy

Module	**Course Contents**	**No of hrs**
1.0	**Nanomaterials in waste water management**	**15**
1.1	Types of nanomaterials in waste management-nanofilters, nanosensors, nanophotocatalysts, and nanoparticles.	
1.2	Porous nanopolymers- Environmental catalysts-Nano biomaterials	
1.3	Nanotechnology: Water and Wastewater Treatment- Nanofilters- Nanoparticles- Nanophotocatalysts- Carbon nanotubes.	
1.4	Catalytic ceramic membranes, Ceramic membranes with zeolite coating- Nano-	

	adsorbents	
Suggested Reading Specific to the module		
1.1	Benefits and Application of Nanotechnology in Environmental Science: an Overview- M. Taran , M. Safaei , N. Karimi , A. Almasi- Article in Biointerface Research in Applied Chemistry , Volume 11, Issue 1, 2021, 7860 - 7870	
1.2	Nanomaterials for Environmental Applications -A. A. Beni , H. Jabbari-Results in Engineering 15 (2022) 100467.	
1.3	Rationally engineered nanosensors: a novel strategy for the detection of heavy metal ions in the environment A. Numan, A.A.S. Gill, S. Rafique, M. Guduri, Y. Zhan, B. Maddiboyina, L. Li, S. Singh, N. Nguyen Dang, J. Hazard Mater, 409 (2021), 124493.	
1.4	Nanotechnology in Environmental Science, First Edition. Edited by C. M. Hussain and A. K. Mishra (2018), Wiley-VCH.	
2.0	**Management of air pollution**	**15**
2.1	Environmental nanosensors -Adsorption of toxic gases- Adsorption of dioxin- Adsorption of CO_2 - Removal of volatile organic compounds	
2.2	Nanomaterials to prevent air pollution-Nanostructured membranes- Catalysts- Nanosensors- Nanocoatings.	
2.3	Nanotubes and nanofiber- Organic-inorganic hybrid membranes	
2.4	Nanotechnology to prevent pollution- Eco-friendly materials- green production	
Suggested Reading Specific to the module		
2.1	Benefits and Application of Nanotechnology in Environmental Science: an Overview- M. Taran, M. Safaei, N. Karimi, A. Almasi- Article in Biointerface Research in Applied Chemistry, Volume 11, Issue 1, 2021, 7860 - 7870	
2.2	Nanomaterials for Environmental Applications -A. A. Beni, H. Jabbari-Results in Engineering 15 (2022) 100467.	
2.3	Nanotechnology in Environmental Science, First Edition. Edited by C. M. Hussain and A. K. Mishra (2018), Wiley-VCH.	

2.4	Environmental and societal impact of nanotechnology-Babatunde, D.E.; Denwigwe, I.H.; Babatunde, O.M.; Gbadamosi, S.L.; Babalola, I.P.; Agboola, O. IEEE Access. 2020, 8, 4640-4667.

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Benefits and Application of Nanotechnology in Environmental Science: An Overview- M. Taran, M. Safaei , N. Karimi , A. Almasi- Biointerface Research in Applied Chemistry , 11, 2021, 7860 – 7870

2 Nanomaterials for Environmental Applications -A. A. Beni, H. Jabbari-Results in Engineering 15 (2022) 100467.

3 Principles of hazardous materials management. Griffin, R.D. 2st edition. CRC Press, 2009.

4 Chapter 7-Nanotechnology: perspective for environmental sustainability -Fulekar, M.H.; Pathak, B.; Kale, R.K.,
Environment and Sustainable Development. Springer India, 2014; pp. 87-114

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Environmental Chemistry in Society (2nd edition)-Beard, J.M., (2013), CRC Press

2 Basic Concepts of Environmental Chemistry (2nd edition). Connell, D.W. (2005), CRC Press.

3 Principles of Environmental Chemistry (3rd edition). Girard, J. (2013), Jones & Bartlett.

4 Chemistry and the Environment. Harnung, S.E. & Johnson, M.S. (2012), Cambridge University Press.

5 Elements of Environmental Chemistry (2nd edition). Hites, R.A. (2012), Wiley & Sons.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Discuss the different types of nanomaterials involved in waste management

2 Describe the various methods involved in waste management process.

3 Analyse the use of nanosensors and nanofilters in waste management.

4 Explain the significance of nanotubes and nanofibres in management of air pollution.

Semester II	
Skill Enhancement Course	
Course Code: **MSNST02SEC01**	Course Name: **Scientific Analysis and Data Collection**

Course Description
This course introduces students with the basic skills for scientific analysis emphasizing on material characterization. A sound background of the basic principles of analysis is involved along with the skills for data collection and analysis.
Course Objectives
1. To teach the principles and practices of various material characterization techniques 2. To impart basic knowledge of spectroscopy techniques like Raman Spectroscopy, Photoluminescence Spectroscopy, UV-Vis Spectrophotometer etc. 3. To teach the students fundamentals of electrochemical characterizations like Cyclic Voltammetry, Galvanostatic Charge/Discharge, Electrochemical Impedance Spectroscopy etc 4. To teach the students on sample preparation methods for different analyses. 5. To make the students aware of data collection and analysis methods

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
2	0	2	30	0	30	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the basic characterization methods for material characterization
C02	Prepare samples for spectroscopy tools
C03	Carry out basic electrochemical characterization methods
C04	Design sample specific analysis set ups for various electrochemical characterizations
C05	Collect and analyse data of different characterization techniques.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Scientific Analysis**	**15**
1.1	Introduction to materials and methods, Fundamentals of Materials Characterization, Basic operation	
1.2	UV-Vis Spectroscopy and Photoluminescence Spectroscopy (Fundamentals, Instrumentation, Qualitative and Quantitative Methodology and applications)	
1.3	XRD and Raman Spectroscopy (Principle, instrumentation and applications), Microscopy techniques	
1.4	Introduction to Experimental Electrochemistry: Electrochemical Work station, (CV, GCD, EIS): Principle and Experimental set up	
Suggested Reading Specific to the module		

1.1	An Introduction to Materials Characterization by P. R. Khangaonkar, Penram International Publishing (India) Pvt. Ltd.	
1.2	Materials Characterization: Introduction to Microscopic and Spectroscopic Methods by Y. Leng (Jun 2, 2008)	
1.3	Encyclopaedia of Materials Characterization C.R.Brundle, C.A.Evans Jr., and S.Wilson (eds), Butterworth-Heinemann,Stoneham, Ma Cullity, B.D., and Stock, R.S., "Elements of X-Ray Diffraction", Prentice-Hall, (2001).	
1.4	Bard and Faulkner, Electrochemical Methods, 2nd ed., Wiley, 2009	
2.0	**Data Collection and analysis**	**15**
2.1	Basics of Data Collection and analysis: Execution of the research - Observation and Collection of data	
2.2	Methods of data collection – Sampling Methods- Data Processing and Analysis strategies – Numerical analysis. Figure Plotting: Figure insertions in documents	
2.3	Data interpretation of microscopic techniques like SEM, TEM and AFM-image analysis, Elemental analysis and structural analysis, Processing and analysis of Scientific images -ImageJ	
2.4	Error analysis: Basic interpretations, standard deviation, variation, correlation coefficient etc. Usage of Packages like ORIGIN and EXCEL,	
Suggested Reading Specific to the module		
2.1	Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International.	
2.2	Research Design, Qualitative, Quantitative and mixed methods approaches by W.Creswell, third edition	
2.3	Collins TJ (July 2007). "ImageJ for microscopy". BioTechniques. 43 (1 Suppl): 25–30	
2.4	Research Design, Qualitative, Quantitative and mixed methods approaches by	

	W.Creswell, third edition

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 An Introduction to Materials Characterization by P. R. Khangaonkar, Penram International Publishing (India) Pvt. Ltd.
2 Materials Characterization: Introduction to Microscopic and Spectroscopic Methods by Y. Leng (Jun 2, 2008)
3 Lynn. J, Frewer, Willehm Norde. R. H, Fischer and Kampers. W. H "Nanotechnology in the Agri- food sector", Wiley-VCH Verlag, 2011.
4 Encyclopedia of Materials Characterization, C.R.Brundle,C.A.Evans Jr., and S.Wilson (eds), Butterworth-Heinemann,Stoneham, Ma.
5 Introductory Raman spectroscopy(Academic Press) J R Ferraro and K Nakamoto.
6 Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International
7 Research Design, Qualitative, Quantitative and mixed methods approaches by W.Creswell, third edition
8 Research Design, Qualitative, Quantitative and mixed methods approaches by W.Creswell, third edition

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Duckett, Simon; Gilbert, Bruce (2000). Foundations of Spectroscopy. Oxford Science Publication
2 Derek Pletcher, A First Course in Electrode Processes, 2nd ed., RSC Publish, 2009.
3 "Introduction to Electron Microscopy". FEI Company. p. 15.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

Marks

End Semester Evaluation 60%

Continuous Evaluation 40%

Sample Questions to test Outcomes.

1. Write a note on the basic principle of UV-Vis spectroscopy?

2.Explain the prerequisites of samples for Raman spectroscopy and describe the principle?

3. Explain how to find the elemental composition of an unknown sample?

4. Give a detailed account on the scientific data collection and analysis?

<table>
<tr><td colspan="9">Skill Enhancement Course II</td></tr>
<tr><td colspan="3">Course Code:

MSNST02SEC02</td><td colspan="6">Course Name:

Technical Writing</td></tr>
<tr><td colspan="9">Course Description</td></tr>
<tr><td colspan="9">Writing and communication skill is very much essential to express scientific ideas or results clearly to validate their significance. For the successful publication of a research work, development of scientific writing skill is essential. The course is divided into two modules. The modules discuss about how a research proposal or manuscript is written for grant, for publication in journals etc. Also a discussion on the importance of seminars and workshops, presentations in such events was mentioned.</td></tr>
<tr><td colspan="9">Course Objectives</td></tr>
<tr><td colspan="9">1 Inculcate scientific writing and communication skill
2 Understand the basic ethical issues confronted by the scientist
3 Recognize the skill areas the student would like to develop
4 Create awareness on the fundamentals of technology transfer</td></tr>
<tr><td colspan="3">Credit</td><td colspan="3">Teaching Hours</td><td colspan="3">Assessment</td></tr>
<tr><td>L/T</td><td>P/I</td><td>Total</td><td>L/T</td><td>P/I</td><td>Total</td><td>CE</td><td>ESE</td><td>Total</td></tr>
<tr><td>2</td><td>0</td><td>2</td><td>30</td><td>0</td><td>30</td><td>40</td><td>60</td><td>100</td></tr>
</table>

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

COURSE OUTCOMES

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Develop skills related to presentation and publication of articles in seminar, book, journals etc.
C02	Understand the scientific paper or thesis writing skill
C03	Realize the ethical issues associated with scientific research and capable to analyze and address unethical situations
C04	Understand the fundamentals of technology transfer and issues related

Module	**Course Contents**	**15 hrs**
1.0	Scientific Writing and Communication Skill	
1.1	Writing Research report, research proposals. Every aspect of writing scientific grants from funding agencies. Introduction to every aspect of grant writing, including selecting funding mechanisms, writing individual grant sections and understanding administrative policies.	
1.2	Strategies for effective scientific writing-core elements of each sections- Principles of writing research manuscript by composing and editing the sections- Familiarization with reference manager- how to peer review an article from the perspective of a researcher-reviewer- journal editor – complete and submit a research manuscript (based on an abstract given), Plagiarism, Ethics, Patent filing	
Suggested Reading Specific to the module		
1.1	The Craft of Scientific Writing, Michael Alley, 4th Ed. Springer, New York, USA (2018).	
1.2	A Guide to the Scientific Career: Virtues, Communication, Research and Academic Writing Edited by Mohammedali M Shoja et.al, Wiley Black well (2019)	

1.3	Handbook of Science Communication by Anthony Wilson, Jane Gregory, Steve Miller, Shirley Earl, IOP Publishing (1999).	
2.0	**Research Presentation and Publication of Research Article**	**15 hrs**
2.1	Power point preparation- Introduction/preample, data display, discussion of results, conclusion, time management, communication.	
2.2	Importance of conferences, seminars,workshops.	
2.3	Publication of a research article in journal: review of literature, status of research problem, developments in research area, data analysis, presentation of results, writing articles, ethics in publishing articles, copy right.	
Suggested Reading Specific to the module		
2.1	Research methodology: (Concepts and Cases) Deepak Chawla, NeenaSondhi	
2.2	Research methodology (Methods and Techniques) CR Kothari, Gaurav Garg	

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 The Craft of Scientific Writing, Michael Alley, 4th Ed. Springer, New York, USA (2018).
2 A Guide to the Scientific Career: Virtues, Communication, Research and Academic Writing Edited by Mohammedali M Shoja et.al, Wiley Black well (2019)
3 Research methodology (Methods and Techniques) CR Kothari, Gaurav Garg

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Research methodology: (Concepts and Cases) Deepak Chawla, NeenaSondhi
2 Handbook of Science Communication by Anthony Wilson, Jane Gregory, Steve Miller, Shirley Earl, IOP Publishing (1999).

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1. Discuss about different types of plagiarism.
2. Give examples to ethical violation in research.
3. Discuss the significance of literature review in research.
4. Give the characteristics of good technical writing.

Skill Enhancement III	
Course Code: **MSNST02SEC03**	Course Name: **Laboratory Skills and Practices**

Course Description

This course provides students with an understanding of basic laboratory procedures, safe working practices using essential equipment and protocols. The course is designed to provide students with an opportunity to gain hands-on experience in the synthesis of nanoparticles using laboratory equipment.

Course Objectives

1 To develop experimental skills.
2 To understand the laboratory safety regulations.
3 To learn the handling of scientific apparatus and instruments.
4 To develop practical skill on different methods of nanomaterial synthesis

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
2	0	2	30	0	30	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Perform laboratory experiments with proper safety measures.
C02	Demonstrate proper procedures for the safe handling of chemicals and laboratory waste management
C03	Formulate the conditions required for the synthesis of different types of nano materials.

Module	Course Contents
1.0	**Laboratory Skills**
1.1	General lab safety rules: Common rules that relate to almost every laboratory, Safety policies, First aid, Use of fire safety, Use of laboratory hood.
1.2	Safe Handling of Hazardous Chemicals: Introduction of hazardous chemicals, Rules for handling chemicals, Essential practices for handling hazardous chemicals, Laboratory waste management.
1.3	Storing, labeling, handling and personal hygiene: Storage and labeling of chemicals, Storage of Explosive and reactive hazardous chemicals, Transportation of hazardous chemicals
Suggested Reading Specific to the module	
1.1	Guidelines for Chemical Laboratory Safety in Academic Institutions, Published by American Chemical Society
1.2	Richard J. Lewis, Sr., Sax's Dangerous Properties of Industrial Materials, 1995
1.3	Peter Urben, Bretherick's Handbook of Reactive Chemical Hazards, Eighth Edition
2.0	**Synthesis of Nanomaterials**
2.1	Metal Nanoparticle Synthesis: Gold, Silver nanoparticle synthesis- green synthesis and chemical synthesis, analysis via UV-Vis spectroscopy. Mechanism of formation. Factors governing particle size.

2.2	Metal oxide Nanoparticle Synthesis: Titanium dioxide, Zinc oxide and Tin oxide synthesis via hydrothermal method and precipitation method. analysis via UV-Vis spectroscopy and XRD.
2.3	Coprecipitation synthesis of magnetic (iron oxide) nanoparticles and analysis via XRD.
Suggested Reading Specific to the module	
1.1	Nanotechnology principles and Practices, Sulabha K Kulkarani.
1.2	Introduction to Nanoscience and Nanotechnology, by K K Chattopadhyay, PHI Learning Pvt. Ltd. New Delhi 2019, ISBN-13: 978-81-203-3608-7.
1.3	Nanostructures and Nanomaterial Synthesis, Properties and Application, Guozhong Cao.

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1, Guidelines for Chemical Laboratory Safety in Academic Institutions, Published by American Chemical Society

2. Richard J. Lewis, Sr., Sax's Dangerous Properties of Industrial Materials, 1995

3. Peter Urben, Bretherick's Handbook of Reactive Chemical Hazards, Eighth Edition

4. Nanotechnology principles and Practices, Sulabha K Kulkarani.

5. Introduction to Nanoscience and Nanotechnology, by K K Chattopadhyay, PHI Learning Pvt. Ltd. New Delhi 2019, ISBN-13: 978-81-203-3608-7.

6. Nanostructures and Nanomaterial Synthesis, Properties and Application, Guozhong Cao

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Prudent Practices in the Laboratory, Handling and Management of Chemical Hazards, Board on Chemical Sciences and Technology, The National Academies Press

2 Louis J. DiBerardinis, Janet S. Baum, Melvin W. First, Gari T. Gatwood, Anand K. Seth, Guidelines for Laboratory Design: Health, Safety, and Environmental Considerations

3 NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd. New Delhi) ISBN-13: 978-0-07-061788-9

4 Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. Publisher: CRC Press (15 December 2008) ISBN-13: 978-1420047790

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

Sample Questions to test Outcomes.

1 Discuss the various safety practices to be followed in the Laboratories of academic Institutes?

2 What are the essential practices to be followed while handling hazardous chemicals?

3 What are the precautions to be taken while handling a) Strong acids, b) explosive chemicals?

4 What are the factors that govern the size of nanoparticle during synthesis?

5 Explain the reason for the color shown by metal nanoparticles of different size.

6 List some of the reducing agents used in the synthesis of gold nanoparticles

Semester II	
Value Added Course	
Course Code: **MSNST02VAC01**	Course Name: **Certificate course in Advanced Techniques for Characterization of Materials**
Course Description	
Characterizations of materials are essential for the applications of the same in various fields	

of material science. This is also important in diverse fields, which includes chemical, microstructure and physical properties of different materials used as probes, sensors and in medical fields.
Course Objectives
The aim of the course is to provide the students with an overview of sophisticated instrumentation techniques emphasized with special reference to the principles, practice and applications of UV-Visible spectroscopy, X-ray diffraction, thermal and electrochemical techniques.

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
2	0	2	30	0	30	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

COURSE OUTCOMES

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the principles and operation of a range of advanced techniques such as UV-Visible spectroscopy, X-ray diffraction, thermal and electrochemical instruments used in characterization of various materials.
C02	Develop an idea about the crystal structure of materials and their by its structure - property relations.
C03	Understanding, from a microstructural point of view, the thermal properties of materials and related applications.
C04	Hand on experience of instruments and interpretation of results. Apply the skills gained in research and industrial explores

Course outcomes based on revised Blooms taxonomy

Module	**Course Contents**	**No. of hrs**
1.0	**Spectroscopic Methods and X-ray Techniques**	**15 hrs**
1.1	Theory of Ultraviolet and Visible Spectroscopy: Electronic transitions, radiative	

	processes, energy diagram	
1.2	Internal conversion, conical intersection, Principle, solvent effects, Instrumentation and applications of UV-Visible, spectroscopy, FT-IR Raman and Fluorescence spectroscopy	
1.3	Principle, Theory- X-ray spectral lines, instrumentation, Powder XRD and Single crystal XRD, X-ray Diffraction, Analysis with X-ray diffraction, applications.	
1.4	Chemical analysis using X-ray absorption, X-ray Fluorescence instrumentation and chemical analysis, Practical: Hands on experience of operation with UV-Vis-, Raman and data analysis.	
1.5	Practical: Instrumentation, sampling and hands on experience with instruments for analysis.	
Suggested Reading Specific to the module		
1.1	Theory and Applications of UV Spectroscopy, H.H. Jaffe and M. Orchin,IBH-Oxford., Introduction to Spectroscopy, Pavia, Brooks/Cole Cenage, 4thedition, 2009, Belmont.	
1.2	Fundamentals of Analytical Chemistry, Skoog, West, Holler, Croach, Thomson Brooks/Cole;	
1.3	Elements of X-ray diffraction by B. D. Cullity	
1.4	Basics Of X Ray Diffraction And Its Applications by K Ramakanth Hebbar	
1.5	Instrumental methods of chemical analysis, Willard, Dean and Merrit, Affiliated East West Press	
2.0	**Thermal Studies and Electrochemical Studies**	**15**
3.1	Theory: Introduction, specific heat, thermal conductivity, thermal expansion, thermal stress, thermal stability. Relationship between structure and thermal properties of materials.Thermo gravimetric methods of analysis (TGA): Instrumentation, thermogram and information from thermogram, factors affecting thermogram, applications TGA for quantitative analysis and problems based TGA.	
3.2	Differential Scanning Calorimetry (DSC): Principle, Instrumentation, Applications Practical: Instrumentation, sampling, Hands on experience of	

	operation with DSC and TGA and interpretation of Data
3.3	Theory: Faradays laws of electrolysis, current - voltage relationship during an electrolysis, operating cell at fixed applied potential, electrolysis at constant working electrode potential. Coulometric methods of analysis. Voltammetric principles, hydrodynamic voltammetry, stripping voltammetry,
3.4	Cyclicvoltammetry (CV),Principle, criteria of reversibility of electrochemical reactions, quasi-reversible and irreversible processes, apparatus, advantages and limitations Instrumentation, sampling and application and interpretation of cyclic voltammograms, Practical: Instrumentation, working, samplings, hands on experience of operation CV and data analysis
Suggested Reading Specific to the module	
3.1	Thermal Analysis From Introductory Fundamentals to Advanced Applications by El-Zeiny Ebeid, Mohamed Zakaria, Thermogravimetric Analysis by Jesse Russell, Ronald Cohn
3.2	Introduction to Thermal Analysis: Techniques and Applications: 1 (Hot Topics in Thermal Analysis and Calorimetry) by M.E. Brown, Principles and Applications of Thermal Analysis by Paul Gabbott
3.3	Fundamentals of Analytical Chemistry, Skoog, West, Holler, Croach, Thomson Brooks/Cole
3.4	Principles of Electroanalytical Methods by Tom Riley, Colin Tomlinson

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1. Instrumental methods of chemical analysis, Willard, Dean and Merrit, Affiliated East West
2. Principles of Electroanalytical Methods by Tom Riley, Colin Tomlinson
3. Fundamentals of electroanalytical chemistry (analytical techniques in the sciences) by Paul M.S. Monk
4. Instrumental methods of chemical analysis, Willard, Dean and Merrit, Affiliated East West
5. Elements of X-ray diffraction by B. D. Cullity
6. Fundamentals of Analytical Chemistry, Skoog, West, Holler, Croach, Thomson Brooks/Cole

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1. Principles of Electroanalytical Methods by Tom Riley, Colin Tomlinson

Teaching Learning Strategies

- Assignments, Internal examinations, Seminars, Semester Viva Voce

Mode of Transaction

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes

1. Discuss the principle of X Ray crystallography.

2. Write down the Debye Scherrer formula for calculating grain size.

3.Briefly explain the principle of X Ray Flourescence.

4. What are the advantages of ATR over other IR sampling techniques?

5. Distinguish between TG, DTG and DTA?

Semester III	
Core Course	
Course Code: **MSNST03DSC09**	Course Name: **Semiconductor Nanomaterials and Nanolithography**
Course Description	

The course give a detailed description about the basics of semiconductors, its properties like conductivity, mobility, carrier concentration, doping concept etc in module one. The probability of carrier distribution in different temperature conditions and their related problems are included. Module two discuss about various semiconductor nanomaterials, their properties, its confinement in different dimensions and applications. Detailed steps involved in the process of different lithographic techniques, their advantages and disadvantages, resist materials specific for each technique are also included in module three. Module four give an in-depth idea related to the nanolithographic techniques using various tools.

Course Objectives

1. To learn about different semiconductors and its properties.
2. To impart knowledge about different areas of semiconductor application.
3. To develop an understanding of different doping methods, carrier concentration and conductivity of semiconductors.
4. To understand the basics of different lithographic techniques.
5. To understand different nanolithography techniques suitable for the design of various nanostructures.

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
4	0	4	72	0	72	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Identify and choose semiconductor materials for a particular application.
C02	Realize the advantages and disadvantages of different lithographic techniques.
C03	Choose a particular lithographic technique for the designing of a nanostructure.

C04	Understand about different resist materials used in various lithographic techniques, their advantages and disadvantages.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Basics of Bulk semiconductors**	**14**
1.1	Introduction-Semiconductor, Types of semiconductors – elemental, compound, direct and indirect band gap semiconductors. Doping – diffusion, Fick's first and second law, ion implantation method, effect of doping and temperature on Fermi level position, Concept of effective mass. Optical properties of semiconductors- Excitons-Phonons-	
1.2	Fermi- Dirac distribution function, probability of occupancy and non-occupancy, Fermi level position in extrinsic and intrinsic semiconductors.	
1.3	Carrier concentration - concentration of electrons, concentration of holes, intrinsic carrier concentration, hall effect.	
1.4	Carrier transport – drift and diffusion, mobility, current density and electrical conductivity.	
	Suggested Reading Specific to the module	
1.1	Semiconductor physics and devices, Naemen Donald ISBN: 9780071070102	
1.2	Physics of Semiconductor Devices, S M Sze, Kwok K Ng, Wiley India Pvt Ltd.	
1.3	Introduction to Solid State Physics, Charles Kittel, Wiley India Pvt Ltd.	
1.4	Solid State Physics, S O Pillai ISBN-13: 9789395161015.	
2.0	**Semiconductor nanostructures**	**20**
2.1	Quantum confinement in one, two and three dimensions: quantum wells, quantum wires, Quantum dots- Superlattices-Band Offsets-Quantum dot lasers.	

	Requirements for an ideal semiconductor nanostructure.
2.2	Epitaxial growth of quantum wells -Lithography and etching Induced dots and wires - Electro statically induced dots and wires.
2.3	Semiconductor nanocrystals - Colloidal quantum dots-Self-assembly techniques - Physical processes in semiconductor nanostructures.
Suggested Reading Specific to the module	
2.1	Nanostructures and Nanomaterial Synthesis, Properties and Application, Guozhong Cao.
2.2	Nanolithography and Patterning Techniques in Microelectronics, David Bucknall.
2.3	Colloidal Quantum Dot Optoelectronics and Photovoltaics, Gerasimos Konstantatos and Edward H. Sargent
3.0	**Basics of Lithography** **20**
3.1	Optical lithography: Contact and proximity printing - Projection Printing – Mask alignment, Reflection and catadioptric projection - Refraction projection – Enhancement – overlay accuracies. Positive and negative photoresists, UV – photolithography for systems of 100 nm – Nano designs for electronic circuits. Etching – wet and dry
3.2	Electron Lithography: Electron optics - Raster scan and Vector scan - Electron proximity / Projection Printing, Electron resists.
3.3	X – ray Lithography: Proximity printing - X-ray masks - X-ray sources - Synchrotron radiation – Xray projection - X-ray resists, Application - LIGA.
3.4	Ion Lithography: Focused ion beam - Point sources of Ion - Ion column - Beam writing – Focused Ion Beam Lithography - Masked Ion Beam Lithography - Ion Projection Lithography.

Suggested Reading Specific to the module	
3.1	Nanostructures and Nanomaterial Synthesis, Properties and Application, Guozhong Cao.
3.2	Robert W. Kelsall, Mark. Geoghegan, Ian W. Hamley, Nanoscale Science and Technology, John Wiley and Sons, 2005 ISBN 0470850868
3.3	James R. Sheats and Bruce W. Amith, "Microlithography Sciences and Technology", Marcel Dekker Inc., New York, 1998.
3.4	John N. Helbert, "Hand Book of VLSI Microlithography", Noyes Publication, USA, 2001.
4.0	**Nanolithography techniques** **18**
4.1	High – resolution E-beam Nanolithography - Resist Exposure Metrics – High resolution resists - Proximity Effects - Direct writing.
4.2	Proximal Probe Nanolithography: STM- material modification- resist exposure and oxidation, material deposition, material removal and etching, manipulation of single atom,– AFM - Dip pen Nano lithography - Resists & Imaging Layers for proximal probes - Anodic Oxidation – Nanoscratching.
4.3	Langmuir – Blodgett Film resists – Patterned synthesis of nanomaterials - Self-Assembled Monolayers Resists
Suggested Reading Specific to the module	
4.1	Nanolithography and Patterning Techniques in microelectronics, David Bucknall.
4.2	Nanolithography – the art of fabricating nanoelectronic and nanophotonicc devices and systems, Martin Feldman.
4.3	Nanostructures and Nanomaterial Synthesis, Properties and Application, Guozhong Cao.

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Robert W. Kelsall, Mark. Geoghegan, Ian W. Hamley, Nanoscale Science and Technology, John Wiley and Sons, 2005 ISBN 0470850868
2 C.Y. Chang and S.M.Sze, "ULSI Technology", McGraw-Hill Companies Inc., Singapore, 1996.
3 John N. Helbert, "Hand Book of VLSI Microlithography", Noyes Publication, USA, 2001.
4 James R. Sheats and Bruce W. Amith, "Microlithography Sciences and Technology", Marcel Dekker Inc., New York, 1998.

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Nanostructures and Nanomaterial Synthesis, Properties and Application, Guozhong Cao.
2 Introduction to Nanoscience and Nanotechnology, by K K Chattopadhyay, PHI Learning Pvt. Ltd. New Delhi 2019, ISBN-13: 978-81-203-3608-7.
3 Nanotechnology principles and Practices, Sulabha K Kulkarani.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Explain the principle and steps involved in photolithography.
2 Derive the expression to obtain the carrier concentration in semiconductors.
3 Explain the process of molecular beam epitaxy in the formation of superlattices.
4 Explain the principle behind the working of quantum dot lasers.

5 Discuss about the different high resolution resist materials used in electron beam lithography.

Semester III	
Core Course	
Course Code: **MSNST03DSC10**	Course Name: **Carbon Nanostructures**

Course Description

The course is divided into four modules. The first module covers the unique geometrical and electronic structure of carbon nanotubes, graphene, fullerenes and other carbon nanomaterials. The growth and synthesis techniques as well as experimental characterization and device applications of carbon nanomaterials are considered elaborately. The reactivity of fullerenes, functionalization reactions of CNTs, etc. are described in detail. The properties of these materials and their significance in specific applications are also included.

Course Objectives

1. To understand the structure and bonding in basic carbon nanostructures like CNTs, fullerenes and graphene
2. To explore the method of synthesis and its role in imparting desired characteristics in the case of various carbon based nanostructures
3. To develop awareness on the properties of carbon nanomaterials
4. To understand various spectroscopic and microscopic tools for the characterization of nanomaterials.
5. To explore the various application areas of carbon nanostructures.

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
4	0	4	72	0	72	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the evolution and various milestones in the development of carbon

	nanostructures
C02	Describe the crystal structure, nature of bonding, classifications etc of carbon nanostructures.
C03	Depict the different synthesis methods, growth mechanisms, reactions and properties of CNTs, fullerenes and graphene.
C04	Explain the different nanostructures like carbon onions, whiskers, cones and nanodiamonds etc. and their structure and properties.
C05	Identify various application areas of CNTs, fullerenes, graphenes and other special carbon nanostructures.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Introduction to Carbon nanostructures**	**14**
1.1	Carbon molecules, nature of the carbon bond, new carbon structures	
1.2	Discovery of C60 structure of C60 and its crystal, Graphene-structure and bonding	
1.3	From a Graphene Sheet to a Nanotube, Single wall and Multi walled Nanotubes, HACM ordering, Zigzag and Armchair Nanotubes, Euler's Theorem in Cylindrical and Defective CNTs	
1.4	structure and properties of Carbon nanowhiskers, Carbon onions, carbon nanocons, nanodiamonds, carbon dots etc.	
Suggested Reading Specific to the module		
1.1	Y. Gogotsi, Carbon nanomaterials, CRC, 2006	
1.2	Echegoyen, L, Diederich, F., and Echegoyen, L.E., Fullerenes: Chemistry, Physics, and Technology, Kadish, K.M. and Ruoff, R.S., Eds.,Wiley, New York, 2000.	
1.3	M. Meyyappan, Carbon Nanotubes, Science and applications, CRC, 2005	
1.4	Jacek D. Wrobel, Preparation and Characterization of Fullerenes, Calif. State University, Hayward, 1996.	
2.0	**Synthesis and properties of Fullerenes**	**20**
2.1	Structure of Higher Fullerenes, Growth Mechanisms; Production and	

	Purification- Fullerene Preparation by Pyrolysis of Hydrocarbons, Partial Combustion of Hydrocarbons, Arc Discharge Methods, Production by Resistive Heating	
2.2	Rational Syntheses of fullerenes- solid, liquid and gaseous state reactions	
2.3	Physical Properties of Fullerenes-, Spectroscopic Properties, Thermodynamic Properties.	
2.4	Chemical Properties- Hydrogenation and Halogenation, cyclopropanation reactions, Nucleophilic Addition to Fullerenes – [2+2], [3+2] and [4+2] cycloadditions.	
2.5	Energy Applications, Electronic Applications and biological Applications of fullerenes	
Suggested Reading Specific to the module		
2.1	Echegoyen, L, Diederich, F., and Echegoyen, L.E., Fullerenes: Chemistry, Physics, and Technology, Kadish, K.M. and Ruoff, R.S., Eds.,Wiley, New York, 2000.	
2.2	Y. Gogotsi, Carbon nanomaterials, CRC, 2006	
2.3	Natalia Kamanina, Fullerenes and Relative Materials: Properties and Applications, IntechOpen, 2018	
2.4	Y. Gogotsi, Carbon nanomaterials, CRC, 2006	
2.5	Carlos Benvegnu, Robert F. Verner, Handbook on Fullerene Synthesis, Properties and Applications, Nova Science Publishers, 2012	
3.0	**Carbon Nanotubes**	**20**
3.1	The Structure of Carbon Nanotubes- Nomenclature, Structure of Single Walled Carbon Nanotubes and Structure of Multiwalled Carbon Nanotubes; Structure and Production of Further Tubular Carbon Materials	
3.2	Characterization of Carbon Nanotubes- Raman Spectroscopy of Carbon Nanotubes: origin of bands, RBM mode,	
3.3	Characterization of Carbon Nanotubes- Infrared Spectroscopy of Carbon Nanotubes, ESR-Spectroscopic Properties of Carbon Nanotubes, XRD.	
3.4	Mechanical, Thermal Applications, Electronic Applications and biological Applications of CNTs	
Suggested Reading Specific to the module		

3.1	M. Meyyappan, Carbon Nanotubes, Science and applications, CRC, 2005	
3.2	Carbon Nanotubes: Properties and Applications- Michael J. O'Connell.	
3.3	Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing	
3.4	Michael J. O'Connell, Carbon Nanotubes Properties and Applications, CRC Press, 2018	
4.0	**Graphene**	**18**
4.1	Structure of graphene; Preparation of graphene – synthesis of graphene by various physical and chemical methods and Purification	
4.2	Electronic Properties Band Structure of Graphene – Dirac points, Mobility and Density of Carriers - Quantum Hall Effect	
4.3	Characterization of of graphene: XRD, XPS, UV-Vis spectroscopy, IR Spectroscopy and Raman spectroscopy	
4.4	Mechanical, Thermal Applications, Electronic Applications and biological Applications of graphene	
Suggested Reading Specific to the module		
4.1	Ajay K. Sood, C. N. R. Rao, Graphene Synthesis, Properties, and Phenomena, Wiley, 2013	
4.2	Athanasios Mitropoulos, George Kyzas, Graphene Materials: Structure, Properties and Modifications, IntechOpen, 2017	
4.3	Alan B. Kaiser, Viera Skakalova, Graphene: Properties, Preparation, Characterization and Applications, Elsevier Science, 2021	
4.4	Jamie H. Warner, Fransizka Schaffel, Mark Rummeli, Alicja Bachmatiuk, Graphene: Fundamentals and Emergent Applications Elsevier Science, 2012	

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1. Y. Gogotsi, Carbon nanomaterials, CRC, 2006
2. Juan Carlos Moreno-Pirajan, S.A Ilangovan, Sabu Thomas, Sarathchandran C., Handbook of Carbon-Based Nanomaterials, Elsevier Science, 2021
3. Nanotubes and Nanowires - C. N. R. Rao and A. Govindaraj, RCS Publishing, 2005.
4. Carbon Nanotubes: Properties and Applications - Michael J. O'Connell, 1st Edition, CRC Press, 2018.
5. Physical properties of Carbon Nanotubes - R. Satio, G. Dresselhaus, M. S. Dresselhaus,

Imperial College Press, 1998.

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Nanoscale materials – Luis M. Liz-Marzan, and Prashant V. Kamat, Springer, 2003

2. Applied Physics of Carbon Nanotubes: Fundamentals of Theory, Optics And Transport Devices - S.V. Rotkin and S. Subramony (Editors), Springer, 2005.

3. Carbon Nanotechnology - Liming Dai (Editor), 1st Edition, Elsevier Science, 2006.4

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1. How do you calculate the number of hexagonal faces in a fullerene structure if the number of Carbon atoms is 86?
2. How does the chirality of CNTs affect their electrical properties?
3. Define chiral angle in carbon nanotubes? How does it vary in the case of various kinds of CNTs?
4. Explain why C60 can be considered as a fairly good electron acceptor?
5. Explain the Generation and reactivity of fullerene carbenes by cyclopropanation reaction?
6. Explain the thermodynamic aspects of fullerenes?
7. Why CNTs are not semi metallic in nature?
8. How ESR spectra can be used to determine the purity of CNTs?

Semester III

Core Course	
Course Code: **MSNST03DSC11**	Course Name: **Nanobiotechnology**

Course Description

Nanobiotechnology refers to the intersection of biology and nanotechnology. The course is divided into four modules. The first module provides basics of biotechnology and bioelectronics with a special emphasis on very large-scale integration circuits. Second module discusses about lipid, protein and DNA nanotechnology and biological computing. Different types of bionanocomposites and their applications are discussed in module 3. Module 4 provide a brief idea of applications of nanobiomaterials in nanoanalytics.

Course Objectives

1. To acquire thorough knowledge of the basics of biotechnology and biology inspired concepts
2. To understand the parts that compose nature's nanomachines: lipids, DNA and proteins
3. To gain familiarity with silicon neuron computational blocks
4. To learn about the use of biological materials such as DNA for making nanohinges, nanowires and nanoglue
5. To understand the basics of biological computing
6. To get familiarize with the characterization methods for nanobiomaterials

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
4	0	4	72	0	72	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Describe the structure of DNA, lipids and proteins.
C02	Explain how nature forms self-organizing supramolecular structures
C03	Explain about tiny rotating nanoturbines in living cells
C04	Summarize the applications of quantum dots in biological labelling
C05	Explain biological application of metal nanoparticles to label biomolecules

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Basics of biotechnology**	**14 hrs**
1.1	Biology inspired concepts, biological networks, biological Neurons,the function of neuronal cell	
1.2	biological neuronal cells on silicon, modeling of neuronal cells by VLSI circuits, spike -event generation, silicon neuron computational blocks, thalamic relay neuron	
1.3	Bioelectronics, molecular Processor, molecular electronics	
1.4	DNA analyzer as biochip, fusion genes microarray, spotted vs in-situ synthesized microarrays	
Suggested Reading Specific to the module		
1.1	Karl Goser, Peter Glösekötter , Jan Dienstuhl, "Nanoelectronics and Nanosystems: From transistors to molecular devices", Springer, 2004	
1.2	Christof M. Niemeyer and Chad A. Mirkin, "Nanobiotechnology Concepts, Applications and Perspectives", Wiley, 2004	
1.3	Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons, Burkhard Raguse, "Nanotechnology Basic Science and Emerging Technologies", CRC Press, 2002	

1.4	Anil K. Deisingh, Adilah Guiseppi-Wilson, and Anthony Guiseppi-Elie, "Biochip Platforms for DNA Diagnostics", Microarrays, 271,2009	
2.0	**Lipid and DNA Technology**	**18 hrs**
2.1	Nano-biometrics :introduction, lipids as nano-bricks and mortar, lipid structure: self-organizing supramolecular structures	
2.2	Proteins: three dimensional structures using 20 amino acids-proteins in nanotechnology: nanomotors	
2.3	Biological computing: A Protein based 3D optical memory based on bacteriorhodopsin	
2.4	Structural and dynamic DNA nanotechnology, sticky ended cohesion, DNA nanostructures, using DNA to build nano cubes and hinges, DNA as smart glue, DNA as wire template, DNA computer	
Suggested Reading Specific to the module		
2.1	Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons, Burkhard Raguse, "Nanotechnology Basic Science and Emerging Technologies", CRC Press, 2002	
2.2	David S. Goodsell, "Bionanotechnology: Lessons from Nature", Wiley-Liss (2004)	
2.3	Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons, Burkhard Raguse, "Nanotechnology Basic Science and Emerging Technologies", CRC Press, 2002	
2.4	Jie Chao, Yunfeng Lin, Huajie Liu, Lianhui Wang and Chunhai Fan DDNA-based plasmonic nanostructures, Mater. Today 480,1-10, 2015	
3.0	**Bionanocomposites**	**20 hrs**
3.1	Natural nano composites – introduction, natural nano composite materials,	

	biologically synthesized nano structures	
3.2	Biologically derived synthetic nano composites, Layered particle-reinforced bionanocomposites	
3.3	Protein based bionanocomposites, DNA based bionanocomposites-polysaccharide based bionanocomposites, biologically inspired nano composites	
3.4	Nanotechnology in Agriculture (Fertilizers and pesticides).	
Suggested Reading Specific to the module		
3.1	Khalid Mahmood Zia, Farukh Jabeen, Saiqa Ikram, "Bionanocomposites: Green Synthesis and Applications", Elsevier, 2020	
3.2	Shakeel Ahmed, Suvardhan Kanchi,"Handbook of Bionanocomposites", Taylor and Francis group, 2018	
3.3	Yury Shchipunov, "Bionanocomposites: Green sustainable materials for the near future", Pure Appl. Chem., Vol. 84, No. 12, pp. 2579–2607, 2012	
3.4	Sunil Kumar Deshmukh, Mandira Kochar, Pawan Kaur, Pushplata Prasad Singh, "Nanotechnology in Agriculture and Environmental Science", CRC Press, 2023	
4.0	**Characterization methods for Nanobiomaterials**	**20 hrs**
4.1	Nanoanalytics, quantum dot biolabeling -passive and active targeting, methods for binding targeting agents to quantum dots: direct binding and adapter mediated binding	
4.2	Nanoparticle molecular labels: Autometallography, immunogold labelling, immunogold silver staining	
4.3	Atomic force microscopy, AFM based Force spectroscopy, analysis of biomolecular structure by AFM and molecular pulling-force spectroscopy– Force spectroscopy measurements of poly protein construct and ligand receptor	

	complexes
4.4	Surface enhanced raman spectroscopy and surface plasmon resonance, biofunctionalized nanoparticles for SERS and SPR.
Suggested Reading Specific to the module	
4.1	Christof M. Niemeyer and Chad A. Mirkin, "Nanobiotechnology Concepts, Applications and Perspectives", Wiley, 2004
4.2	Peter M. Lackie, "Immunogold silver staining for light microscopy", Histo-chem Cell Biol,106, 9, 1996
4.3	Youngkyu Kim, Woong Kim, and Joon Won Park "Principles and Applications of Force Spectroscopy Using Atomic Force Microscopy" Bull. Korean Chem. Soc. 2016
4.4	Christof M. Niemeyer and Chad A. Mirkin, "Nanobiotechnology Concepts, Applications and Perspectives", Wiley, 2004

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1. Christof M. Niemeyer and Chad A. Mirkin, "Nanobiotechnology Concepts, Applications and Perspectives", Wiley, 2004
2. Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons, Burkhard Raguse, "Nanotechnology Basic Science and Emerging Technologies", CRC Press, 2002
3. David S. Goodsell, "Bionanotechnology : Lessons from Nature", Wiley-Liss, 2004

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1. Khalid Mahmood Zia, Farukh Jabeen, Saiqa Ikram, "Bionanocomposites: Green Synthesis and Applications", Elsevier, 2020
2. Shakeel Ahmed, Suvardhan Kanchi, "Handbook of Bionanocomposites", Routledge Taylor and Francis group,2018

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

4. Write a note on artificial nervous systems.
5. Explain spike-event generation in artificial neurons.
6. Explain the formation of a Holliday junction and a stiff double crossover (DX) molecule.
7. Write a short note on DNA based computing.
8. Summarize the properties of bionanocomposites and their applications.
9. List out common methods for synthesizing starch blends–based bionanocomposites.
10. Explain the challenges associated with the application of quantum dots in bioimaging.
11. Give a short note on nanoparticle molecular labels.

Semester III	
Core Course	
Course Code: **MSNST03DSC12**	Course Name: **Research Project**
Course Description	
The course aims at providing the students with an opportunity of performing a research project in the field of nanomaterials under supervision and to make them learn the scientific skills like literature review, data analysis, scientific writing etc	
Course Objectives	
• To make the students carry out an individual research-based project in the field of nanoscience • To acquire scientific problem solving skills, data collection, analysis and report the research findings	

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
0	4	4	0	200	200	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

COURSE OUTCOMES

Course Learning Outcomes: At the end of the course, the student will be able to

C01	Identify a problem area in a specific field and formulate new scientific questions
C02	Carry out a literature review based on the given keywords
C03	Propose a hypothesis to solve a particular problem
C04	perform a research project according to the proposed hypothesis
C05	Analyse the experimental results and represent the data accurately
C06	document results by writing a research report

Semester III	
Core Course	
Course Code: **MSNST03DSC13**	Course Name: **Industrial Visit**
Course Description	
Industrial visits are intended to provide the students an opportunity to interact with a live working industry or a premier institute. The students learn about the latest technological innovations and research and developments in different related fields which would help them to choose their career in the future.	
Course Objectives	
To make the students 1 To have an opportunity to interact with professionals, entrepreneurs and academic experts 2 To provide an insight into the real working environment and to have an exposure to cutting edge technologies and facilities	

Credit	Teaching Hours	Assessment

L/T	P/I	Total	L/T	P/I	Total	CE	ESE	Total
0	2	2	0	0	0	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

COURSE OUTCOMES

Course Learning Outcomes: At the end of the course, the student will be able to

C01	Explain the functioning of the industry/research labs, the principles they follow and the work management system.
C01	Explain how the theories and principles they have learned are being implemented in a live working industry.

Semester III

Elective Course

Course Code:	Course Name:
MSNST03DSE07	**Nano Medicine and Drug Delivery Systems**

Course Description

This course focuses on biomedical uses of nanotechnologies. The course will cover nanoscale advanced drug delivery systems fundamentals, design, synthesis, and uses. This course provides essential knowledge in field of Nanomedicine.

Course Objectives

1. To get an overview of the exciting and emerging discipline of nanomedicine.
2. To understand the specific aspects of nanomaterials as applied to biology and medicine
3. To learn about the essential role of nanosensors in medical field.
4. To understand the role of controlled, and targeted delivery systems for drugs and genetic materials using polymeric systems, colloidal drug delivery systems.

5	To develop knowledge on different properties and structure of nanocarriers used for drug delivery							
Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Summarise the background and history of Nanomedicine
C02	Examine the role of nanosensors in medical field
C03	Apply the principles and technology in the design of controlled release drug delivery systems.
C04	List the criteria for selection of a drugs and nanocarriers for the development of novel drug delivery systems
C05	Interpret the formulation of novel nanoparticles-based drug delivery systems

Course outcomes based on revised Blooms taxonomy

Module	**Course Contents**	**No of hrs**
1.0	**Prospect of Nano-Medicine**	**13 hrs**
1.1	History of the idea – The Biological and Mechanical Traditions – Nano-medicine - Taxonomy	
1.2	Bio-Pharmaceuticals -Biomaterials-types of biomaterials-composite biomaterials uses of biomaterials.	
1.3	Implantable Materials – Implantable Devices – Biomaterials used in implantable devices, Surgical Aids – Diagnostic Applications-Diagnostic	

	Tools.
1.4	Genetic Testing – Imaging – Nanoparticles Probe- Case Analysis – Resiprocytes – Mechanical Artificial Red Cells-type of resiprocytes.
Suggested Reading Specific to the module	
1.1	Nanomedicine Technologies and Applications, (2nd Edition) by Thomas Webster, Elsevier.
1.2	Biopharmaceuticals: Biochemistry and Biotechnology by Gary Walsh Wiley-Blackwell; 2nd edition (2003)
1.3	Biomaterials and Implant Biocompatibility, A. Cîmpean and F. Miculescu, MDPI books
1.4	Imaging Genetics (1st Edition) by A. Dalca, K. Batmanghelich, M. Sabuncu, Li Shen, Elsevier.
2.0	**Nanosensors** **14 hrs**
2.1	Types of sensors in nanomedicine-Chemical and Molecular Sensors – Displacement and Motion Sensors.
2.2	Force Nanosensors – Pressure Nanosensors – Thermal Nanosensors
2.3	Electric and Magnetic Sensing – Cellular Bioscanning – Non-invasive Neuroelectric Monitoring.
2.4	Macrosensing – Types of macrosensing-Acoustic Macrosensing -Electric and Magnetic Macrosensing – Neural Macrosensing.
Suggested Reading Specific to the module	
2.1	Nanosensors by Vinod Kumar Khanna, CRC Press (2016)
2.2	Handbook of modern sensors-Physics, Designs and applications (5^{th} edition) by Jacob Fraden, Springer.

2.3	Nanomedicine and Nanosafety-Recent Trends and clinical evidences, M. K. Das and Y. V Pathak, Springer.
2.4	Nanomedicine, Volume I: Basic Capabilities by R. A. Freitas Jr., Landes Bioscience.
3.0	**Drug delivery basics** **14 hrs**
3.1	Ideal drug delivery systems-Needs and Requirements – Factors influencing the drug delivery– Localized and targeted drug delivery-Controlled drug delivery-Active targeting and passive targeting.
3.2	Nanostructured delivery systems-Advantages of nanostructured delivery systems- Properties of nanoparticles affecting drug delivery- Polymeric Nanoparticles as Drug Carriers-types of polymer carriers-preparation of polymeric nanocarriers.
3.3	Genetic Vaccine-examples-Liposomes- Structure-properties and drug delivery applications – Polymer Micelles as Drug Carriers – Types of polymer micelles-Recent Advances in Microemulsions as Drug Delivery Vehicles
3.4	Lipoproteins-Structure-properties and applications as Pharmaceutical Carriers – Solid Lipid Nanoparticles as Drug Carriers-Structure and properties.
Suggested Reading Specific to the module	
3.1	Nanomedicine in Drug Delivery, A. Kumar, H. M. Mansour, A. Friedman, E. R. Blough, CRC Press.
3.2	Nanomedicines Design, Delivery and Detection by M. Braddock The Royal Society of Chemistry (2016)
3.3	Understanding Nanomedicine- An Introductory Textbook by R. Burgess, CRC Press.
3.4	Nanomaterials-Synthesis, Properties and Applications by A.S. Edelstein and R.C Cammarata, Institute of Physics Publishing.

4.0	**Nanocarriers** **13 hrs**
.4.1	Nanocapsules – A New Drug Delivery System- Nanocapsules preparation, Characterization and Therapeutic Applications – Dendrimers as Nanoparticulate Drug Carriers – structure and properties of dendrimers.
4.2	Cells and Cell Ghost as Drug Carriers – Cochleates as Nanoparticular Drug Carriers – Aerosols as Drug Carriers-Types of aerosols-Magnetic Nanoparticles as Drug Carriers.
4.3	Nanoparticulate Drug Delivery to the Reticuloendothelial System and to Associated Disorders – Delivery of Nanoparticles to the Cardiovascular System – Nanocarriers for the Vascular Delivery of Drugs to the Lungs – Nanoparticulate Carriers for Drug Delivery to the Brain.
4.4	Nanoparticles for Targeting Lymphatics – Polymeric Nanoparticles for Delivery in the Gastro-Intestinal Tract – Nanoparticular Carriers for Ocular Drug Delivery – Nanoparticles and Microparticles as Vaccines Adjuvants – Pharmaceutical Nanocarriers in Treatment and Imaging of Infection.
Suggested Reading Specific to the module	
4.1	Nanoparticulates as Drug Carriers Edited by Vladimir P.Torchilin, Imperial College Press, (2006)
4.2	Novel Drug Delivery Systems by Y. Chien, CRC Press, (2019)
4.3	Drug Delivery Systems by R. K. Tekade, Elsevier Science, (2019)
4.4	Controlled Drug Delivery: Fundamentals and Applications, Second Edition, J. Robinson, V. H. L. Lee, Taylor & Francis.

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

12. Nano Medicines Edited by Dr.Parag Diwan and Ashish Bharadwaj, Pentagon Press(2006) ISBN 81-8274-139-4

13. Nanoparticulates as Drug Carriers Edited by Vladimir P.Torchilin, Imperial College Press, (2006) ISBN 1-86094-630-5
14. Nanomedicine by K.A. Howard, T. V. Jensen, D. Peer, Springer
15. Novel Drug Delivery Systems by D. K. Tripathi, A. Alexander, PharmaMed Press / BSP Books (2019)
16. Drug Delivery Systems (second edition) by J.B. Cannon, M. A. Hollinger, and V. V. Ranade, CRC press.

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Novel Platforms for Drug Delivery Applications, S. Das, S. Thomas, P. P. Das, Elsevier Science, (2022)
2 Frontiers in Nanomedicine, Volume 1, M. L. Bondi, C. Botto, E. Amore, Bentham Science Publishers, (2015)
3 The Handbook of Nanomedicine, K. K. Jain, Springer Science & Business Media, (2008)

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 List some examples of implantable materials and devices used in nanomedicine.
2 Summarize the history of nanomedicine
3 Compare the principle and functions of chemical and molecular sensors.
4 Distinguish between pressure sensors and molecular sensors
5 Analyze the role of cells and cell ghosts as drug carriers.

6 Sketch the structure of dendrimers and its application in drug delivery.

7 Discuss the vascular delivery of drugs into lungs using nanocarriers

8 Examine the role of polymeric nanoparticles in the Gastro-Intestinal Tract.

Semester III	
Elective Course	
Course Code: **MSNST03DSE08**	Course Name: **Organic Nanomaterials**

Course Description

This Course will include an in-depth discussion of different organic nanomaterials and different applications for this class of material. Preparative and synthetic approaches to organized, assembled, discrete organic nanomaterials will be described in this course.

Course Objectives

1. To explain different types of organic nanomaterials
2. To understand and apply the applications of organic nanomaterials
3. To learn the preparative methods of organic nanomaterials
4. To understand the fundamentals of organic nanomaterials and self-assembled organic nanostructures.

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	To Investigate the key aspects of organic nano materials
C02	To Interpret specific properties of organic nanomaterials
C03	To Classify different types of organic nanostructures.
C04	To Summarize the synthetic methods of organic nanomaterials

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Basic concepts**	**14**
1.1	Introduction to organic nanomaterials- basic structure- size- size to volume ratio	
1.2	Special properties-Comparison with inorganic nanomaterials- Significance	
1.3	Organic -Inorganic hybrid nanomaterials and its properties- Chemical Composition- Morphology	
	Suggested Reading Specific to the module	
1.1	Organic Nanomaterials: Synthesis, Characterization, and Device Applications- T. Torres, G. Bottari (2013), John Wiley & Sons	
1.2	Single Organic Nanoparticles- H. Masuhara, H. Nakanishi, K. Sasaki, (2003), Springer Science & Business Media,	
1.3	Organic-Inorganic Hybrid Nanomaterials - S. Kalia, Y. Haldorai, Springer	
2.0	**Types of organic nanomaterials**	**14**
2.1	Liposomes-structure and its properties- Dendrimers- structure and its properties and polymeric micelles.	
2.2	Carbon based nanomaterials- tubes- wires- graphene- Organic Semiconductors-organic light emitting devices (OLEDs)	
2.3	Polymer based nano materials- polymer conjugates- amphiphilic polymers- Polymer micelles- Vesicles-Nanocapsules-Structure and its properties	

Suggested Reading Specific to the module		
2.1	Nanomaterials in Biomedical Application and Biosensors (NAP-2019): 244 by A. D. Pogrebnjak, M. Pogorielov, R. Viter, Springer Proceedings in Physics.	
2.2	Handbook of Carbon-Based Nanomaterials edited by Sabu Thomas C. Sarathchandran. S.A. Ilangovan, J. C. Moreno-Piraján (2021), Elsevier	
2.3	Polymer Science and Nanotechnology Fundamentals and Applications edited by R. Narain (2020) Elsevier Science	
3.0	**Synthetic strategies**	**13**
3.1	Top-down techniques-Milling- microfluidics and lithography-Nanofabrication-	
3.2	Bottom up-techniques-supramolecular self-assembly- solvent-free techniques and solvent displacement techniques-	
3.3	Divergent and convergent methods in dendrimers- interfacial polymerization-nanoprecipitation- emulsion–diffusion, double emulsification.	
Suggested Reading Specific to the module		
3.1	Organic Nanomaterials: Synthesis, Characterization, and Device Applications- T. Torres, G. Bottari (2013), John Wiley & Sons	
3.2	Organic Nanomaterials: Synthesis, Characterization, and Device Applications- T. Torres, G. Bottari (2013), John Wiley & Sons	
3.3	Polymer Science and Nanotechnology Fundamentals and Applications edited by R. Narain (2020) Elsevier Science	
4.0	**Applications of organic Nanomaterials**	**13**
4.1	Organic nanomaterials for biomedical applications- organic nanomaterials as drug delivery systems.	
4.2	Dentistry-tissue engineering bone regeneration – osteolyelitis treatment-cancer treatment.	
4.3	Organic nanomaterials as sensors-food nanotechnology- Energy Applications-Solar cells.	

Suggested Reading Specific to the module	
4.1	Nanomaterials in Biomedical Application and Biosensors by A. D. Pogrebnjak, M. Pogorielov, R. Viter, Springer Proceedings in Physics.
4.2	Nanomaterials in Biomedical Application and Biosensors by A. D. Pogrebnjak, M. Pogorielov, R. Viter, Springer Proceedings in Physics.
4.3	Applications of Nanomaterials in Sensors and Diagnostics Edited by A. Tuantranon (2013), SpringerLink

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Organic Nanomaterials: Synthesis, Characterization, and Device Applications-

T. Torres, G. Bottari (2013), John Wiley & Sons

2 Single Organic Nanoparticles- H. Masuhara, H. Nakanishi, K. Sasaki, (2003), Springer Science & Business Media.

3 Polymer Science and Nanotechnology Fundamentals and Applications edited by R. Narain (2020) Elsevier Science

4 Nanomaterials in Biomedical Application and Biosensors by A. D. Pogrebnjak, M. Pogorielov, R. Viter, Springer Proceedings in Physics.

5 Handbook of Carbon-Based Nanomaterials edited by Sabu Thomas C. Sarathchandran. S.A. Ilangovan, J. C. Moreno-Piraján (2021), Elsevier

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao, Imperial college Press, (2006). Publisher: World Scientific Publishing Company; 2 edition (4 January 2011) ISBN-13: 978-9814324557

2. Springer Handbook of Nanotechnology - Bharat Bhusan Publisher: Springer-Verlag (15 May 2006) ISBN-13: 978-35403436603.

3. Introduction to Nanoscale Science & Technology, Di Ventra, Evoy, Heflin, Springer Science, NY, 2004. Publisher: Springer; 1 edition (30 June 2004)

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Differentiate organic and Inorganic nanomaterials

2. Summarize the scope of organic nanomaterials in biomedical field

3. Discuss the various types of organic nanomaterials with examples

4. Describe the applications of organic nanomaterials

5. Discuss the structure and properties of liposomes.

6. Classify the organic nanomaterials based on their building blocks.

7. Discuss the synthetic method of organic nanomaterials

8. Examine the role of dendrimers in drug delivery.

Semester III	
ELECTIVE COURSE	
Course Code: **MSNST03DSE09**	Course Name: **Nanophotonics**
Course Description	

The course provides the basics and principles of nanophotonics/ nano-optics. An introduction to the three cornerstones of the future photonic technologies, viz., nanophotonics, plasmonics, and metamaterials, covering their fundamentals and latest advancements are discussed. The nano-sized structures gives access to new optical properties and functionalities that are not available in bulk materials. The course will first cover the principles of photonic crystals, metal optics, surface plasmon resonance and their applications. The basics and applied aspects of nanophotonics i.e. controlling, guiding, and manipulating electromagnetic radiation at the nanoscale will be discussed.
Course Objectives
1 To provide a comprehensive view of nanoscale optical materials and photonics 2 To impart knowledge about how light interactw with nanostructures and the related phenomena. 3 To impart knowledge about the quantum confinement effect and optical properties of nanomaterials. 4 To impart knowledge about the concept of metamaterials: composite materials that have been nanostructured to obtain a specific dielectric response.

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

COURSE OUTCOMES

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Identify different types of materials and know their typical optical properties.
C02	Understand the atomic mechanisms of different optical phenomena, such as

	absorption, scattering and emission.
C03	Express the quantum confinement effects in optical properties of materials.
C04	Examine plasmonic effects in metal nanoparticles

Module	**Course Contents**	
1.0	**Foundation of Nanophotonics**	**14 hrs**
1.1	Photons and Electrons- a comparison of their similarities and dissimilarities, confinement of photons and electrons.	
1.2	Optical interaction at the nanoscale: Axial localisation-Evanascent waves, Surface Plasmon, Total internal reflection.	
1.3	Lateral localisation- apertureless confinement and confinement with aperture.	
Suggested Reading Specific to the module		
1.1	Principles of Nano-Optics, Lukas Novotny and Bert Hecht.	
1.2	Introduction to Nanophotonics, Sergey V. Gaponenko, Cambridge University Press, New York, ISBN-13 978-0-521-76375-2 (2010).	
1.3	Surface Plasmon Nanophotonics, Mark L. Brongersma, Pieter G. Kik.	
2.0	**Quantum-Confined Materials**	**14 Hrs**
2.1	Nanoscale confinement of electronic interactions- quantum confinement effect, Quantum confined structures: Quantum wells, Quantum wires, Quantum dots. Optical transitions-absorption, Luminescence.	
2.2	Quantum confined stark effect, dielectric confinement effect,nanoscopic interaction dynamics.	
2.3	Light propagation in nanostructures-nanowires, nano-waveguides, Combining	

	emission and propagation: Nanolasers -laser basics, nanowire lasers.	
Suggested Reading Specific to the module		
2.1	Principles of Nanophotonics, M Ohtsu, K Kobayashi, T Kawazoe, T Yatsui and MNuruse, CRC Press, 2008.	
2.2	Devices, Circuits and Systems: Nanophotonics, P P Yupapin, K Srinuanjan, S Kamoldilok, Pan Stanford Publishing, 2013.	
2.3	Nanophotonics, Heve Rigneault and Jean–Michel Lourtioz, ISTE (2006).	
3.0	**Photonic Crystals and Metamaterials**	**13 Hrs**
3.1	Basics concepts, Bandgap and band structures in two and three dimensional lattices. Periodic structures in nature, Experimental methods of fabrication, Photonic crystal fibers (PCF).	
3.2	Plasmonic enhancement of secondary radiation, classification of secondary radiations, Enhancement of emission and scattering of light, Local density of states in plasmonic nanostructures. Hot-spots in plasmonic nanostructures, Raman scattering enhancement in metal–dielectric nanostructures, Luminescence enhancement in metal–dielectric nanostructures	
3.3	Metamaterials concept; Effective medium theories: Maxwell–Garnett theory, Bruggeman theory. Anisotropic mixtures: multilayers and wire media; Negative-permittivity and negative-permeability metamaterials; Double-Negative Materials.	
Suggested Reading Specific to the module		
3.1	Fundamentals of Photonics, 3rd Edition, Bahaa E. A. Saleh, Malvin Carl Teich.(2019). Photonic crystals: Physics and Technology, (Eds.) C. Sibilia, T. M. Benson, M. Marciniak, T. Szoplik, (ISBN: 978-88-470-0843-4) (2008).	

3.2	Photonic Crystals, John D. Joannopoulos, Robert D. Meade, Joshua N. Winn	
3.3	Optical Metamaterials: Fundamentals and Applications, W. Cai and V. Shalaev Springer	
4.0	**Nanophotonics for Diagnostics and Therapy**	**13 Hrs**
4.1	Nanophotonics for Diagnostics – Surface plasmons on nanoparticles and surfaces, Raman spectroscopy based systems, Fluorescence based systems	
4.2	Nanophotonics bioimaging- magnetic resonance imaging, optical coherence tomography, photoacoustic imaging, two – photon luminescence, QD's for invivo imaging	
4.3	Nanophotonics for therapy- Plasmonic photothermal therapy, photodynamic therapy.	
Suggested Reading Specific to the module		
4.1	Introduction to Biophotonics, Paras N. Prasad, (John Wiley and Sons, New Jersey), ISBN: 0- 471-28770-9 (2003).	
4.2	Plasmonic Biosensors: An Integrated View of Refractometric Detection, by A.B. Dahlin	
4.3	Fundamentals of Photonics, 3rd Edition. by Bahaa E. A. Saleh, Malvin Carl Teich.(2019)	

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

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

2 Fundamentals of Photonics, 3rd Edition, Bahaa E. A. Saleh, Malvin Carl Teich.(2019).

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

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

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 1 Devices, Circuits and Systems: Nanophotonics, P P Yupapin, K Srinuanjan, S Kamoldilok, Pan Stanford Publishing, 2013.
2 Fundamentals of Photonics, 3rd Edition. by Bahaa E. A. Saleh, Malvin Carl Teich.(2019)
3 Principles of Nanophotonics, M Ohtsu, K Kobayashi, T Kawazoe, T Yatsui and MNuruse, CRC Press, 2008.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Describe the principle and working of photonic crystal?
2 What is Quantum confinement effect?
3 Discuss the principle involved in photodynamic therapy.
4 Explain Maxwell–Garnett theory.

Semester III	
Multidisciplinary Elective Course	
Course Code: **MSNST03MDC01**	Course Name: **Introduction to Nanotechnology**

Course Description
This course provides basic overview of nanomaterials and their applications. The course includes the study of chemical composition, synthesis, characterization, application and environmental impacts of nanomaterials.

Course Objectives	
1	To learn the basic concepts of nanoscience and nanotechnology
2	To develop the knowledge on the synthesis of nanomaterials
3	To impart the idea of different environmental impacts of nanotechnology
4	To understand the potential application areas of nanotechnology
5	To introduce basic tools and principles relevant to the nanoscale systems.

Credit			**Teaching Hours**			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
4	0	4	72	0	72	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Summarise the background and history of Nanotechnology
C02	Demonstrate different methods of synthesis of nanomaterials.
C03	Analyze the environmental effects of nanotechnology
C04	Apply the application of nanotechnology in various potential areas.
C05	Apply knowledge of nanoscience and nanotechnology in design of different nanomaterials.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No of hrs
1.0	**Introduction to Nanotechnology**	**18hrs**
1.1	Evolution of Nanotechnology- Nanomaterials in the Medieval History- Nanomaterials in Indian culture.	
1.2	Feynmann's vision on Nano Science & technology-History of Modern nanotechnology- Major milestones.	
1.3	The concept of 'Grey goo'-Nanotechnology in nature-Biomimetics- Introduction to Nanomaterials	
1.4	Siegel's classifications-Carbon based nanostructures-Special Nanomaterials	
Suggested Reading Specific to the module		
1.1	G. Cao and Y.Wang, Nanostructures and Nanomaterials, 2nd Ed., Imperial College	
1.2	Bharat Bhushan, "Springer Handbook of Nanotechnology", Barnes & Noble 2004.	
1.3	Mark. A, Ratner and Daniel Ratner, "Nanotechnology: A Gentle Introduction to the Next Big Idea, Pearson, 2003.	
1.4	Introduction to Nanoscience, G.L. Hornyak, J. Dutta, H.F. Tibbals, A.K. Rao, CRC Press.	
2.0	**Synthesis of Nanomaterials**	**18 hrs**
2.1	Introduction to the synthesis of Nanomaterials-Top-down and Bottom-up approaches-Wet chemical synthesis methods-	
2.2	Gas phase production methods-Biological Synthesis-Physical method of nanomaterial synthesis Lithographic Techniques.	
2.3	Photolithography, positive and negative resist materials, exposure methods X-Ray lithography, synchrotron, LIGA, Ion beam lithography	
2.4	Introduction to Nanocomposites including polymer nanocomposites, Synthesis	

	methods for various nanocomposite materials.
Suggested Reading Specific to the module	
2.1	Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao , Imperial college Press, (2006), World Scientific Publishing Company; 2 edition (2011).
2.2	Nanomaterials and Nanochemistry by C. Brechignac.P. Houdy M. Lahmani, Springer-Verlag (2007). (For Unit III-Part I Chapter I)
2.3	James R. Sheats and Bruce W. Amith, "Microlithography Sciences and Technology", Marcel Dekker Inc., New York, 1998.
2.4	Mai. Y-W "Polymer Nano composites", Woodhead publishing, 2006.
3.0	**Environmental impacts of Nanotechnology 18hrs**
3.1	Various sources of nanomaterials in the environment-entry routs of nanomaterials to human body.
3.2	Cellular uptake of nanomaterials and biotoxicity-impact of nanomaterials on specific organs.
3.3	Effects of Nanomaterials on the Cardiovascular System- Nanomaterials in the Liver and Gastrointestinal Tract.
3.4	Effects of NP on the Nervous System- Nanomaterials as environmental pollutants: Air, water and soil.
Suggested Reading Specific to the module	
3.1	Challa S.S.R. Kumar, Nanomaterials: toxicity, health and environmental issues, Wiley-VCH, 2006.
3.2	Nanoscale Science and Technology, R. Kelsall, I.Hamley and M. Geoghegan, Wiley, 2005.

3.3	K. J Klabunde, R. M. Richards, Nanoscale Materials in Chemistry, 2nd Ed., Wiley, 2009.
3.4	T. Pradeep, A text book of Nano Science and Technology, Tata McGraw-Hill Education, 2012.
4.0	**Applications and Future aspects 18hrs**
4.1	Introduction to the potential application areas of Nanotechnology- biological applications- metal nanoparticles-Nanorobotics–Drug delivery-liposomes-dendrimers- quantum dots -Photodynamic Therapy-Nanomaterials in bone substitutes and dentistry – Implants - CNT-based nanomaterials as scaffolds or implants in bone tissue.
4.2	Nanomaterials used in energy and environmental applications and their properties, Solar energy, solar cells, dye sensitized solar cell, organic solar cells-Nanomaterials for Environmental Remediation-Soil pollution-air pollution-water pollution.
4.3	Applications of nanomaterials in agriculture and food processing-Nanotechnology in Agriculture - Insecticides using nanotechnology –Potential of nano-fertilizers – Potential benefits in Nanotechnology in Food industry – Food processing - Packaging- Nanomaterials in cosmetics and textiles.
4.4	Defence and Aerospace applications- Detection and diagnostics of chemical and biological agents- Nanotechnology enabled bio chemical weapons - Nanotechnology based satellite communication system.
Suggested Reading Specific to the module	
4.1	Nanoparticulates as Drug Carriers Edited by Vladimir P.Torchilin, Imperial College Press, (2006)
4.2	Jingbio louise Liu, Sajid Bashir, Advanced Nanomaterials and their applications in Renewable energy, Elsevier, 2015.
4.3	Nanotechnology in agriculture and food production, Jennifer Kuzma and Peter

	Ver Hage, Woodrow Wilson International Center, 2006.
4.4	Margaret. E, Kosal, Nanotechnology for Chemical and Biological defence, Springer 2009

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

17. Brown. P. J and Stevens. K Nanofibers and Nanotechnology in Textiles, Woodhead Publishing Limited, Cambridge, 2007.
18. Biomedical Nanotechnology, Neelina. H, Malsch (Ed.), CRC Press 2005.
19. Novel Drug Delivery Systems by D. K. Tripathi, A. Alexander, PharmaMed Press / BSP Books (2019)
20. Micro and nanotechnology for space systems the aerospace corporation, Helvajian. H and. Robinson. E.Y, Micrograph, 1997.
21. A text book of Nano Science and Technology, T. Pradeep, Tata McGraw-Hill Education, 2012.

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

22. Novel Platforms for Drug Delivery Applications, S. Das, S. Thomas, P. P. Das, Elsevier Science, (2022)
23. Introduction to Nanoscience", S.M. Lindsay, Oxford
24. NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Sketch the structure of dendrimers and explain its properties.
2 Summarize the application of quantum dots in biomedical field
3 Give an account on endocytosis based cellular uptake of nanoparticles.
4 List the properties of blood brain barrier.
5 Compare exohedral and endohedral fullerenes with examples
6 Explain the various synthesis methods of graphene
7 Classify the different types of photoresist materials used in lithography
8 Discuss about the different areas of application of nanocomposites.

Semester IV	
Core Course	
Course Code: **MSNST04DSC14**	Course Name: **External Research Project**
Course Description	
The course aims at providing the students with an opportunity of performing a research project in the field of nanomaterials under supervision and to make them learn the scientific skills like literature review, data analysis, scientific writing etc	
Course Objectives	
• To make the students carry out an individual research-based project in the field of nanoscience • To acquire scientific problem solving skills, data collection, analysis and report the research findings	

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
0	12	12	0	480	480	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

COURSE OUTCOMES

Course Learning Outcomes: At the end of the course, the student will be able to

C01	Identify a problem area in a specific field and formulate new scientific questions

C02	Carry out a literature review based on the given keywords
C03	Propose a hypothesis to solve a particular problem
C04	perform a research project according to the proposed hypothesis
C05	Analyse the experimental results and represent the data accurately
C06	document results by writing a research report

Semester IV	
Elective Course	
Course Code: **MSNST04DSE10**	Course Name: **Industrial Significance and Applications of Nanotechnology**
Course Description	
The course discusses about the application of nanotechnology in the different fields. Module one discusses about various biomedical application of nanomaterials like dentistry, drug delivery, cancer treatment, tissue engineering etc. Application of nanomaterial and technology in the field of agriculture, nanofertililers and its type, role of nanofertilizers in improving crop yield, advantages and disdvantages of nanofertilizers over conventional fertilizers are listed. Benefits of nanotechnology in food packaging are included. Various nanomaterial application in the field of nanocosmeceuticals and nanomaterial translocation and health risks are included. Improvement in properties of nanoparticle incorporated textile materials and its wide range application is listed in module three. Module four discuss about the application of nanomateriuals and technology in the field of defence and aerospace industry.	
Course Objectives	
1 To understand the application of nanomaterials and its derivatives in medical field. 2 To understand the advantages of using nanoparticles in the field of agriculture, food packaging etc. 3 To impart a knowledge on nanomaterial application in the field of cosmetics and textile industry.	

4	To discuss about the properties of nanomaterials for its use in military and aerospace industry.							
Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Learn about different nanocomposite materials, its properties and application.
C02	Discover different areas of nanomaterial application.
C03	Realize the advantages and disadvantages of nanomaterial application in different fields like medical, agriculture, aerospace, military, food packaging etc.
C04	Realize the toxic effects of nanomaterials to environment.

Course outcomes based on revised Blooms taxonomy

Module	**Course Contents**	**No. of Hrs**
1.0	**Biomedical Applications**	**13**
1.1	Nanoparticles and Micro–organism- Biosensors- Bioreceptors and their properties - Biochips- Integrated nanosensor networks for detection and response- DNA based biosensors and diagnostics.	
1.2	Natural nanocomposite systems; spider silk, bones, shells - Nanomaterials in bone substitutes and dentistry, Implants and Prosthesis –Tissue Engineering	
1.3	Neuroscience -Neuro-electronic Interfaces -Nanorobotics– Photodynamic	

	Therapy - Protein Engineering – Nanosensors in Diagnosis–Drug delivery – Cancer therapy and other therapeutic applications.
Suggested Reading Specific to the module	
1.1	Neelina. H, Malsch (Ed.), "Biomedical Nanotechnology", CRC Press 2005.
1.2	Mai. Y-W "Polymer Nano composites", Woodhead publishing, 2006.
1.3	Bharat Bhushan, "Springer Handbook of Nanotechnology", Barnes & Noble 2004.
2.0	**Agricultural and Food Sector Applications 14**
2.1	Nanotechnology in Agriculture -Precision farming, Smart delivery systems – Insecticides using nanotechnology – Potential of nano-fertilizers –-Information and communication technology- Sensors- RF identification- Food safety- Nanomaterial based Food diagnostics – Contaminant detection – Intelligent packaging- Nanoengineered Food ingredients- Potential risks to Nanofood to consumers.
2.2	Potential benefits in Nanotechnology in Food industry – Global Challenges- Product innovation and Process improvement- Consumer benefits- Food processing - Packaging- - Packing materials.
2.3	Physical properties- Improvements of mechanical and barrier properties- Antimicrobial functionality- Active packaging materials.
Suggested Reading Specific to the module	
2.1	Jennifer Kuzma and Peter Ver Hage, "Nanotechnology in agriculture and food production", Woodrow Wilson International Center, 2006.
2.2	Lynn. J, Frewer, Willehm Norde. R. H, Fischer and Kampers. W. H "Nanotechnology in the Agri- food sector", Wiley-VCH Verlag, 2011.
2.3	Mark. A, Ratner and Daniel Ratner, "Nanotechnology: A Gentle Introduction to

	the Next Big Idea", Pearson, 2003.
3.0	**Applications in Textile and Cosmetics Sector** **14**
3.1	Nanofibre production – Electrospinning and charge injection-method – morphological control- yarns and polymide nanofibers- Carbon Nanotube and Nanofibre Reinforced Polymer Fibres- multifunctional polymer nanocomposites
3.2	Improvement of polymer functionality- Nylon-6 nanocomposites from polymerization- Dyeable Polypropylene - nanocoatings and surface modifications.
3.3	Nano-filled polypropylene fibers - UV resistant, antibacterial, self-cleaning, flame retardant textiles – Lightweight bulletproof vests and shirts, Colour changing property, Waterproof and Germ proof, Cleaner kids clothes, Wired and Ready to Wear textiles.
3.4	Cosmetics; Formulation of Gels, Shampoos, Hair-conditioners–Nanomaterials in Sun-screen UV protection – Color cosmetics
Suggested Reading Specific to the module	
3.1	Brown. P. J and Stevens. K "Nanofibers and Nanotechnology in Textiles", Woodhead Publishing Limited, Cambridge, 2007.
3.2	Brown. P. J and Stevens. K "Nanofibers and Nanotechnology in Textiles", Woodhead Publishing Limited, Cambridge, 2007.
3.3	Mark. A, Ratner and Daniel Ratner, "Nanotechnology: A Gentle Introduction to the Next Big Idea", Pearson, 2003.
4.0	**Defense and Aerospace Applications** **13**
4.1	Pathways to Physical protection- Detection and diagnostics of chemical and biological agents, methods- Chemical and Biological counter measures- Decontamination- Post exposure and pre-exposure protection and decontamination.

4.2	Nanotechnology enabled bio chemical weapons- Influence operations- Evasion of medical countermeasures.
4.3	Nanotechnology based satellite communication system- Guidance, Navigation and control- Spacecraft thermal control- mini, micro, nanosatellite concepts- Fiber optic and Chemical microsensors for space craft and launch support.
4.4	Micro/Nano pressure and temperature sensors for space missions.
Suggested Reading Specific to the module	
4.1	Margaret. E, Kosal, "Nanotechnology for Chemical and Biological defence, Springer 2009.
4.2	Margaret. E, Kosal, "Nanotechnology for Chemical and Biological defence, Springer 2009.
4.3	Helvajian. H and. Robinson. E.Y "micro and nanotechnology for space systems" the aerospace corporation, Micrograph , 1997.

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Mark. A, Ratner and Daniel Ratner, "Nanotechnology: A Gentle Introduction to the Next Big Idea", Pearson, 2003.

2 Bharat Bhushan, "Springer Handbook of Nanotechnology", Barnes & Noble 2004.

3 Neelina. H, Malsch (Ed.), "Biomedical Nanotechnology", CRC Press 2005.

4 Udo. H, Brinker, Jean-Luc Mieusset (Eds.), "Molecular Encapsulation: Organic Reactions in Constrained Systems", Wiley Publishers 2010.

5 Jennifer Kuzma and Peter Ver Hage, "Nanotechnology in agriculture and food production", Woodrow Wilson International Center, 2006.

6 Lynn. J, Frewer, Willehm Norde. R. H, Fischer and Kampers. W. H "Nanotechnology in the Agri- food sector", Wiley-VCH Verlag, 2011.

7 Brown. P. J and Stevens. K "Nanofibers and Nanotechnology in Textiles", Woodhead Publishing Limited, Cambridge, 2007.

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Mai. Y-W “Polymer Nano composites”, Woodhead publishing, 2006.
2 Chang. W.N “Nanofibres fabrication, performance and applications”, Nova Science Publishers Inc, 2009.
3 Helvajian. H and. Robinson. E.Y “micro and nanotechnology for space systems” the aerospace corporation, Micrograph , 1997.
4 Margaret. E, Kosal, “Nanotechnology for Chemical and Biological defence, Springer 2009.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 Write a note on the modification of spider silk by inorganic nanomaterials.
2 Explain Colorimetric Nanosensors for the Diagnostics of Infectious Diseases.
3 Explain in detail how the electric field, magnetic field and thermal treatment are used for cancer therapy.
4 Explain the principle of flame retardant finish on nano-engineered fabric.
5 Write a note on nanocarriers for drug delivery.

Semester IV	
Elective Course	
Course Code: **MSNST04DSE11**	Course Name: **Nanoelectronics**

Course Description
The course introduces students to the fundamentals of nanoelectronics, nanodevices, spintronics and molecular electronics. Quantum mechanics behind nanoelectronics along with other principles and the operations of the same are also covered. A detailed section on various kinds of FETs are also included in this course.

Course Objectives
1. To learn the basic concepts of nanoelectronics 2. To study the basic tools for micro and nanofabrication 3. To develop the knowledge on the different quantum electronic devices 4. To understand the idea of molecular electronics and bioelectronics. 5. To impart theoretical knowledge on different memory devices and sensors

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the basics of Nanoelectronics.
C02	Analyze the different tools for micro and nano fabrication
C03	Distinguish between molecular electronics and bioelectronics.
C04	Explain the principle and fabrication of memory devices.
C05	Summarize the different type of FETs and its properties

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Basics of Nanoelectronics**	**14**
1.1	Basics of nano electronics – Contribution of Nanoelectronics to Mankind	
1.2	Physical fundamentals – The birth of electronics – Phase shifters, piezoelectric sensors and actuators	
1.3	Ultrasonic transducers, optical limiters, energy harvesters, MOSFETs, The tools	

	for micro and nano fabrication	
1.4	Basics of Lithographic techniques for nano electronic devices-basics of information theory.	
	Suggested Reading Specific to the module	
1.1	Hanson, Fundamentals of Nanoelectronics, Pearson Education, 2009	
1.2	Livio Baldi, Marcel Van de Voorde, Robert Puers, Sebastiaan E. van Nooten, Nanoelectronics Materials, Devices, Applications, Wiley, 2021	
1.3	K.Goser, P. Glosekotter, J. Dienstuhl, Nanoelectronics and Nanosystems: From transistors to molecular devices., Springer (2004)	
1.4	Nanotechnology: basic science and emerging technologies – Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons, Burkhard Raguse, Overseas Press (2005).	
2.0	**Quantum Electronic Devices**	**14**
2.1	Basics of Quantum electronic devices – The journey from classical physics to quantum physics: upcoming electronic devices	
2.2	Fundamentals to understand the evolution of quantum electronics- electrons in mesoscopic structure	
2.3	short channel MOS transistor – split gate transistor – electron wave transistor – electron spin transistor – quantum cellular automate – quantum dot array	
2.4	principles of Single Electron Transistor (SET) – SET circuit design – comparison between FET and SET circuit design-Coulomb Blockade effect.	
	Suggested Reading Specific to the module	
2.1	Quantum Transport: Atom to Transistor, Supriyo Datta, Cambridge University Press, 2005	
2.2	Dietrich Marcuse, Principles of Quantum Electronics, Elsevier Science, 1980	
2.3	Massimo Macucci, Quantum Cellular Automata: Theory, Experimentation and Prospects, Imperial College Press, 2006	
2.4	Hanson, Fundamentals of Nanoelectronics, Pearson Education, 2009	
3.0	**Molecular Electronics and Bioelectronics**	**13**
3.1	Tunneling devices and super conducting devices – tunnelling element technology	
3.2	RTD – circuit design based RTD –Defect tolerant circuits	

3.3	Molecular electronics – elementary circuits – flux quantum devices – applications of super conducting devices	
3.4	Bioelectronics – molecular processor – DNA analyzer as biochip – DNA computer – Quantum computer	
	Suggested Reading Specific to the module	
3.1	Hans Koch, Heinz Lübbig, K.v. Klitzing, Single-Electron Tunneling and Mesoscopic Devices, Springer Berlin Heidelberg, 1992	
3.2	C. Tejedor, E.E. Mendez, L.L. Chang, Resonant Tunneling in Semiconductors Physics and Applications, Springer US, 2012	
3.3	Steven T. Ruggiero, Superconducting Devices, Elsevier Science, 2013	
3.4	Eugenii Katz, Itamar Willner, Bioelectronics, From Theory to Applications, Wiley, 2006	
4.0	**Memory Devices and Sensors**	**13**
4.1	Nano ferroelectrics - ferroelectric random access memories – introduction – Fe RAM circuit design – ferroelectric thin film properties and integration – Ferroelectric capacitors	
4.2	Sensors based on nanotubes and Nanowires (Metal Oxide nanostructures for Gas flow, Temperature and strain sensors)	
4.3	Nano designs and Nano contacts – Molecular nanowires-Organic LED-principle-fabrication-device architecture-application -limitations-	
4.4	Organic FETs- CNT and Graphene FETs, SiNW FET etc. electronic noses – semiconductor sensor array	
	Suggested Reading Specific to the module	
4.1	Nanoelectronics and Nanosystems: From transistors to molecular devices. K.Goser, P. Glosekotter, J. Dienstuhl, Springer (2004)	
4.2	Francisco J. Arregui, Sensors Based on Nanostructured Materials, Springer US, 2010	
4.3	N. Thejo Kalyani, Hendrik C. Swart, Sanjay J. Dhoble, Principles and Applications of Organic Light Emitting Diodes (OLEDs), Elsevier Science, 2017	
4.4	Zhenan Bao, Jason Locklin, Organic Field-Effect Transistors, CRC Press, 2018	

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Nanoelectronics and Nanosystems: From transistors to molecular devices. K.Goser, P. Glosekotter, J. Dienstuhl, Springer (2004)

2. Nanoelectronics and information technology: Advanced electronic materials and novel devices (2nd edition), Rainer Waser (Ed.), Wiley-VCH Verlag, Weiheim (2005).
3. Nanotechnology: basic science and emerging technologies – Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons, Burkhard Raguse, Overseas Press (2005).
4. Transport in Nanostructures, D. K. Ferry and S. M. Goodwick, Cambridge Univ. Press. Cambridge, UK, 2001 Reprint, Ch. 4. 2. Physics of Semiconductor devices, J. P. Colinge and C. A. Colinge, Kluwer Academic Pub, 2002, Dordrech.
5. Quantum Transport: Atom to Transistor, Supriyo Datta, Cambridge University Press, 2005

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Nano and Molecular Electronics Handbook, Edited by Sergey Edward Lyshevski, CRC Press,
(2007).

2. Organic Chemistry, Jonathan Clayden, Stuart Warren, Nick Greeves, Oxford University Press
3. Organic Chemistry, T. W. Graham Solomons, Craig B. Fryhle, Scott A. Snyder, Wiley
4 Blanksby, S. J.; Bowie, J. H. (2005). "Carbanions: formation, structure and thermochemistry". The encyclopedia of mass spectrometry. Gross, Michael L., Caprioli, R. M. (1st ed.). Amsterdam: Elsevier.
5 Steric and Stereoelectronic Effects in Organic Chemistry, V. K. Yadav, Springer, 2016
6. Photochemistry And Pericyclic Reactions, Jagdamba Singh, Jaya Singh, New age international

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%

Continuous Evaluation	40%

Sample Questions to test Outcomes.

1. Give brief account on piezoelectric sensors?
2. Explain the principle and significance of phase shifters?
3. What could be the role of thin film nanostructures in Transistors?
4. Give a comparison of the circuit designs of FET and SET?
5. Discuss the working of a quantum cellular automaton using a five-dotdevice?
6. Explain in detail the evolution, structure, and theory of RTDs?
7. Explain the Relationship between Wang Tiles and Branched Junctions in thecontext of DNA based computing?
8. Discuss the common materials being used in OLED applications?

ELECTIVE COURSE	
Course Code: **MSNST04DSE12**	Course Name: **Nanotechnology- Society, Ethics and Legal Aspects**
Course Description	
The course will provide an understanding of the socio economic impact of nanotechnology and to handle the techniques effectively. The intricate relationship between technology, society and ethics is also addressed. The course also discuss about the laws and legal risks related to nanotechnology.	
Course Objectives	
1 To impart knowledge about the legal aspects related to nanotechnology. 2 To impart knowledge about the economic impact of nanotechnology. 3 Understand the various social impacts of nanotechnology trend and research. 4 To impart knowledge about the ethics related to nanotechnology.	

Credit	**Teaching Hours**	**Assessment**

L/T	P/I	Total	L/T	P/I	Total	CE	ESE	Total
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

COURSE OUTCOMES

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Understand the laws and legal risks of nanotechnology.
C02	To provide awareness about socio economic impact of nanotechnology and to handle the techniques effectively.
C03	To enhance the nanotechnology research by taking ethics and public opinion into consideration, professional and ethical responsibility.
C04	Understand the product scaling up in nanotechnology.

Module	Course Contents	
1.0	**Economic and societal impact of nanotechnology**	**14 Hrs**
1.1	Socio-Economic Impact of Nanoscale Science- Managing the Nanotechnology Revolution: Consider the Malcolm Baldrige National Quality Criteria - The Emerging Nano Economy: Key Drivers, Challenges, and Opportunities	
1.2	Transcending Moore's Law with Molecular Electronics and Nanotechnology - Semiconductor Scaling as a Model for Nanotechnology Commercialization - Sustaining the Impact of Nanotechnology on Productivity, Sustainability, and Equity.	
1.3	Navigating Nanotechnology Through Society - Nanotechnology, Surveillance, and Society: Methodological Issues and Innovations for Social Research - Nanotechnology: Societal Implications: Individual Perspectives - Nanotechnology and Social Trends - Five Nanotech Social Scenarios-Technological Revolutions	

	and the Limits of Ethics in an Age of Commercialization - Vision, Innovation, and Policy.	
Suggested Reading Specific to the module		
1.1	Mihail C. Roco and William Sims Bainbridge ―Nanotechnology: Societal Implications IIIndividual Perspectives‖, Springer (2007).	
1.2	Jurgen Schulte ―Nanotechnology: Global Strategies, Industry Trends and Applications‖, John Wiley & Sons Ltd (2005).	
1.3	Mark. R. Weisner and Jean-Yves Bottero ― Environmental Nanotechnology applications and impact of nanomaterial‖, The McGraw-Hill Companies (2007)	
2.0	**Ethics and Society**	**14 Hrs**
2.1	Approaching the nano age, Nanotechnology: revolution or evolution, societal dimensions of nanotechnology, ethical dimension of science and technology, the language of ethics, methods and processes in ethics.	
2.2	Emerging issues: nanomaterials and manufacturing, military and national security implications, sustainability and environment.	
2.3	Nanotechnology in health and medicine, in search of healthy future, Nanotechnology and personalized medicine.	
Suggested Reading Specific to the module		
2.1	Nanotechnology Ethics and Society, Deb Bennett-Woods, CRC Press	
2.2	Geoffrey Hunt and Michael D. Mehta ―Nanotechnology: Risk, Ethics and Law, Earthscan/James & James publication (2006).	
2.3	Geoffrey Hunt and Michael. D, Mehta ―Nanotechnology: Risk, Ethics and Law, Earthscan/James & James publication, 2006.	
3.0	**Legal Aspects**	**13 Hrs**

3.1	Protection –Patents, copyright, trade secrets, ownership of nanotech intellectual properties.	
3.2	Regulation- Delegation of power to agencies, example of regulation of nanotechnology, environmental regulation, regulation of exports, political and judicial control over agency action.	
3.3	Liability-civil liability, warranty, class action, criminal liability	
Suggested Reading Specific to the module		
3.1	Nanotechnology Legal Aspects, Patrick M Boucher, CRC Press	
3.2	Gehrke, Pat J., Nano-Publics: Communicating Nanotechnology Applications, Risks, and Regulations, Palgrave Macmillan (2018)	
3.3	Geoffrey Hunt and Michael D. Mehta ―Nanotechnology: Risk, Ethics and Law, Earthscan/James & James publication (2006).	
4.0	**Public Perceptions and Education**	**13 Hrs**
4.1	Public Perceptions-Societal Implications of Nanoscience: An Agenda for Public Interaction Research -Communicating Nanotechnological Risks- A Proposal to Advance Understanding of Nanotechnology‘s Social Impacts.	
4.2	Nanotechnology in the Media: A Preliminary Analysis-Public Engagement with Nanoscale Science and Engineering -Nanotechnology: Moving Beyond Risk Communication Streams and Nanotechnology	
4.3	The (Re) Interpretation of a New Technology Nanotechnology: Societal Implications — Individual Perspectives-Historical Comparisons for Anticipating Public Reactions to Nanotechnology.	
Suggested Reading Specific to the module		
4.1	Harald Throne-Holst, Eivind Soto, Pal Strandbakken, Gerd Scholl, Consumers and Nanotechnology: Deliberative Processes and Methodologies, CRC Press (2018)	

4.2	Jurgen Schulte ―Nanotechnology: Global Strategies, Industry Trends and Applications‖, John Wiley & Sons Ltd, 2005.
4.3	Mark. R, Weisner and Jean-Yves Bottero ―Environmental Nanotechnology applications and impact of nanomaterial‖, The McGraw-Hill Companies, 2007.

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1. Mihail C. Roco and William Sims Bainbridge ―Nanotechnology: Societal Implications IIIndividual Perspectives‖, Springer (2007).
2. Mark. R. Weisner and Jean-Yves Bottero ― Environmental Nanotechnology applications and impact of nanomaterial‖, The McGraw-Hill Companies (2007)
3. Nanotechnology Legal Aspects, Patrick M Boucher, CRC Press
4. Geoffrey Hunt and Michael D. Mehta ―Nanotechnology: Risk, Ethics and Law, Earthscan/James & James publication (2006).

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1. Harald Throne-Holst, Eivind Soto, Pal Strandbakken, Gerd Scholl, Consumers and Nanotechnology: Deliberative Processes and Methodologies, CRC Press (2018).
2. Geoffrey Hunt and Michael D. Mehta ―Nanotechnology: Risk, Ethics and Law, Earthscan/James & James publication (2006).
3. Jurgen Schulte ―Nanotechnology: Global Strategies, Industry Trends and Applications‖, John Wiley & Sons Ltd (2005).
4. Mark. R. Weisner and Jean-Yves Bottero ― Environmental Nanotechnology applications and impact of nanomaterial‖, The McGraw-Hill Companies (2007).

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%

Continuous Evaluation	40%

Sample Questions to test Outcomes.

1 How nanotechnology affects the society?

2 Discuss about the ethical risk of nanotechnology.

3 Discuss about the social issues of nanotechnology in workspace?

4 Discuss about the ethical and legal challenges in nanomedical innovations.

Semester I	
Elective Course	
Course Code: **MSNST01DSE13**	Course Name: **Prospects and Challenges of Nanotechnology**

Course Description

This is an elective course, designed to build a basic knowledge of applications of various nanomaterials in different areas. First two modules explain biomedical applications of nanomaterials. The third module explains the role of nanotechnology in other fields such as civil infrastructure, automobiles, agriculture, food industry and energy storage. The fourth module describes the concerns and challenges of nanotechnology in the afore mentioned areas.

Course Objectives

1 To introduce students recent developments and utilization of different nanomaterials in various fields such as medicine, automobiles, agriculture etc.

2 To make students aware of risk factors, toxicity and health issues associated with the utilization of nanomaterials

3 To understand safety parameters and protection laws associated with applications of nanomaterials.

4 To understand the advantages of nanomedicine over traditional medicine.

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**

3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the role of nanomaterials in diagnostics
C02	Analyze the advantages of nanomedicine over traditional medicine
C03	Describe advantages and disadvantages of nanobiomedical engineering
C04	Explain emerging applications of nanomaterials in agriculture and its challenges.
C05	List out recent developments and applications of nano materials in different areas.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of hrs
1.0	**Prospects of nanotechnology in medicine**	**14 hrs**
1.1	The golden era of nanotechnology; Applications in life slowing diseases. role of nanomaterials in diagnostics,	
1.2	Dendrimer: A Promising Nanocarrier for Cancer Therapy, nanomedicines in cardiology. Synthesis, storage and characteristics of Doxil. Biomedical Applications of Graphene	
1.3	Advantages of nanomedicine over traditional medicine, challenges of nanotechnology in medicine	
Suggested Reading Specific to the module		
1.1	Nazrul Islam, “Nanotechnology: Recent Trends, Emerging Issues and Future Directions”, Nova Publications, 2014	

1.2	Yi Ge, Songjun Li, Shenqi Wang, Richard Moore, “Nanomedicine Principles and Perspectives”, springer, 2014	
1.3	B.K. Parthasarathy, “Challenges and Opportunities in Nanotechnology”, Isha Books 2007	
2.0	**Nanobiomedical engineering**	**14 hrs**
2.1	MRI, Molecular machines, fluorescent imaging, Emission tomography, medical device implantation, Advantages and disadvantages	
2.2	Nanobiomedical engineering and its challanges, use of nanocomposites, nanoconcreate and nanofibers in repairing, replanting and substituting bones, tooth and veins.	
2.3	Tissue engineering- Advantages and disadvantages.	
Suggested Reading Specific to the module		
2.1	Ray, Shariqsrijon Sinha and Bandyopadhyay, Jayita. "Nanotechnology-enabled biomedical engineering: Current trends, future scopes, and perspectives" *Nanotechnology Reviews*, vol. 10, no. 1, 2021, pp. 728-743.	
2.2	Liu, S., Lin, R., Pu, C., Huang, J., Zhang, J., & Hou, H. (2022). Nanocomposite Biomaterials for Tissue Engineering and Regenerative Medicine Applications. IntechOpen. doi: 10.5772/intechopen.102417	
2.3	David Williams, “Benefit and risk in tissue engineering”, Materials Today, Volume 7, Issue 5, 2004, Pages 24-29	
3.0	**Emerging Applications of Nanomaterials**	**13 hrs**
3.1	Application of Nanotechnology in Civil Infrastructure and automobiles: Current Status and Future Potential	
3.2	Nanomaterials in agriculture- pesticides, fertilizers and fluid medicines for growth. Advantages and limitations	

3.3	Application in food industry, colorants, anticaking, drying and antimicrobial agents. Nanomaterials application in solar cells and LED**s.**	
Suggested Reading Specific to the module		
3.1	Mohajerani A, Burnett L, Smith JV, Kurmus H, Milas J, Arulrajah A, Horpibulsuk S, Abdul Kadir A. "Nanoparticles in Construction Materials and Other Applications, and Implications of Nanoparticle Use". Materials (Basel). 2019 Sep 20;12(19):3052.	
3.2	Y. Ghidan, A., & M. Al Antary, T. (2020). Applications of Nanotechnology in Agriculture. IntechOpen. doi: 10.5772/intechopen.88390	
3.3	Woei Jye Lau, Kajornsak Faungnawakij, Kuakoon Piyachomkwan, Uracha Rungsardthong Ruktanonchai, In Micro and Nano Technologies, "Handbook of Nanotechnology Applications", Elsevier, 2021	
4.0	**Concerns and challenges of nanotechnology**	**13 hrs**
4.1	Challenges in nanomaterial formation: Green Nanotechnology approach	
4.2	Toxicity of Nanoparticles. Lack of instrumentation and its maintenances and calibration, health problems associate with lungs, skin and vision.	
4.3	Risk factors in handling and storing nanomaterials. Safety parameters and protection laws.	
Suggested Reading Specific to the module		
4.1	Verma A, Gautam SP, Bansal KK, Prabhakar N, Rosenholm JM. Green Nanotechnology: Advancement in Phytoformulation Research. Medicines (Basel). 2019 Mar 14;6(1):39	
4.2	Priyanka Ganguly, Ailish Breen and Suresh C. Pillai Toxicity of Nanomaterials: Exposure, Pathways, Assessment, and Recent Advances, *ACS Biomater. Sci. Eng.* 2018, 4, 7, 2237–2275	
4.3	Maria Batool, Muhammad Faizan Nazar, Muhammad Bilal Tahir, Muhammad Sagir, Saira Batool, Chapter 10 - Nanomaterial safety regulations, Editor(s):	

	Muhammad Bilal Tahir, Muhammad Sagir, Abdullah M. Asiri, In Micro and Nano Technologies, Nanomaterials: Synthesis, Characterization, Hazards and Safety, Elsevier, 2021, Pages 259-272

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Nazrul Islam, "Nanotechnology: Recent Trends, Emerging Issues and Future Directions", Nova Publications 2014

2 B.K. Parthasarathy, "Challenges and Opportunities in Nanotechnology", Isha Books 2007

3 Toby Shelley, "Nanotechnology: New Promises, New Dangers", Zed Books Ltd 2006

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Yi Ge, Songjun Li, Shenqi Wang, Richard Moore, "Nanomedicine Principles and Perspectives", springer, 2014

2 Woei Jye Lau, Kajornsak Faungnawakij, Kuakoon Piyachomkwan, Uracha Rungsardthong Ruktanonchai, In Micro and Nano Technologies, "Handbook of Nanotechnology Applications", Elsevier, 2021

3 Ray, Shariqsrijon Sinha and Bandyopadhyay, Jayita. "Nanotechnology-enabled biomedical engineering: Current trends, future scopes, and perspectives" *Nanotechnology Reviews*, vol. 10, no. 1, 2021, pp. 728-743.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

6 Explain the role of nanomaterials in diagnostics

7 Write a short note on advantages of nanomedicine over traditional medicine.

8 Explain nanobiomedical engineering

9 Describe recent developments and applications of nano materials in agriculture.

Semester IV	
Elective Course	
Course Code: **MSNSTDSE14**	Course Name: **Nanosensors and their Applications**

Course Description

This is an elective course, comprising of four modules. First module gives a brief introduction about sensors, their characteristics and physical effects involved in signal transduction. Second and third modules explain the fundamental concepts of inorganic and organic/bio sensors. Fourth module describes emerging applications of nanosensors in various fields.

Course Objectives

5 To understand static and dynamic characteristics of sensors.

6 To explain physical effects involved in signal transduction of sensors.

7 To list out different types of inorganic and organic sensors.

8 To explain biomedical applications of nanosensors.

Credit			**Teaching Hours**			**Assessment**		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain sensor characteristics and physical effects involved in signal transduction.

C02	Classify various kinds of inorganic nanosensors
C03	Explain general configuration and basic principle of different biosensors
C04	Explain emerging applications of nanosensors in biomedicine
C05	List out different classes of materials used for biosensors.

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of hrs
1.0	**Sensor Characteristics and Physical Effects**	**14 hrs**
1.1	Active and Passive sensors – Static characteristic - Accuracy, resolution, drift, sensitivity, hysteresis, repeatability and linearity – Dynamic characteristics	
1.2	First and second order sensors -types of sensors- Temperature Sensors, Smoke Sensors - Pressure Sensor -sound sensor-light sensor	
1.3	Physical effects involved in signal transduction- Photoelectric effect – Photo dielectric effect – Photoluminescence effect – Electroluminescence effect – Hall effect – Thermoelectric effect – Piezoelectric effect – Pyroelectric effect — Magneto resistive effect.	
Suggested Reading Specific to the module		
1.1	Kourosh Kalantar – Zadeh, Benjamin Fry, "Nanotechnology- Enabled Sensors", Springer, 2008.	
1.2	Vinod Kumar Khanna, "Nanosensors: Physical, Chemical, and Biological", Publisher: CRC Press,2021	
1.3	Vijay.K.Varadan, Linfeng Chen, Sivathanupillai, "Nanotechnology Engineering in Nano and Biomedicine", John Wiley & Sons, 2010.	
2.0	**Introduction to inorganic nanosensors**	**13 hrs**

2.1	Density of states (DOS) – DOS of 3D, 2D, 1D and 0D materials	
2.2	One dimensional gas sensors:- gas sensing with nanostructured thin films – absorption on surfaces – metal oxide modifications by additives – surface modifications	
2.3	Nano optical sensors – nano mechanical sensors – surface plasmon resonance nanosensors – anisotropic, Giant and colossal magneto resistors – magnetic tunneling junctions.	
Suggested Reading Specific to the module		
2.1	James Patterson, Bernard Bailey, "Solid state physics Introduction to the theory", Springer, 2007	
2.2	Ghenadii Korotcenkov, "Handbook of Gas Sensor Materials Properties, Advantages and Shortcomings for Applications Volume 1: Conventional Approaches", springer, 2013	
2.3	Vinod Kumar Khanna, "Nanosensors: Physical, Chemical, and Biological", Publisher: CRC Press,2021	
3.0	**Fundamental concepts of organic/biosensors**	**14 hrs**
3.1	General configuration of biosensor; Generations of biosensors; Basic principle of different biosensors: electrochemical, optical, acoustic, piezoelectric, and calorimetric biosensors	
3.2	Biological recognition systems: enzyme, antibody, nucleic acid, cell, and tissue; Properties of ideal materials for biosensors	
3.3	Classes of materials for biosensors: polymers, material containing metal complex, sol-gel materials, nanomaterials, composite materials, metal oxides, photonic crystals, and zeolite materials	
Suggested Reading Specific to the module		

3.1	**Aiguo Wu**, **Waheed S. Khan, "**Nanobiosensors: From Design to Applications", Wiley-VCH Verlag GmbH, 2020	
3.2	Jerome Schultz, Milan Mrksich, Sangeeta N. Bhatia, David J. Brady, Antonio J. Ricco, David R. Walt, Charles L. Wilkins, "Biosensing: International Research and Development", Springer, 2006	
3.3	Inamuddin, Tauseef Ahmad Rangreez, Mohd Imran Ahamed, Abdullah M. Asiri "**Biosensors – Materials and Applications"** Materials Research Foundations, Vol. 47. 2019	
4.0	**Emerging Applications of Nanosensors**	**13 hrs**
4.1	Cantilever array sensors - Cantilever sensors for diagnosis of diabetes mellitus - Cantilever sensors for cancer diagnosis	
4.2	Nanotube based sensors - Nanotube based sensors for DNA detection - Nanotube based sensors for capnography	
4.3	Nanowire based sensors - Nanowire based electrical detection of single viruses - Nanowire based electrical detection of biomolecules.	
Suggested Reading Specific to the module		
4.1	Hans Peter Lang, Martin Hegner, Christoph Gerber, "Cantilever array sensors", Materials Today, Volume 8, Issue 4, 2005, Pages 30-36	
4.2	Swasti Saxena, Ankit Kumar Srivastava, "Chapter 10 - Carbon nanotube-based sensors and their application", Editor(s): Sabu Thomas, Yves Grohens, Guillaume Vignaud, Nandakumar Kalarikkal, Jemy James, Micro and Nano Technologies, Nano-Optics, Elsevier, 2020, Pages 265-291	
4.3	Fernando Patolsky, Charles M. Lieber, "Nanowire nanosensors", Materials Today, Volume 8, Issue 4, 2005, Pages 20-28	

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

4 Kourosh Kalantar – Zadeh, Benjamin Fry, “Nanotechnology- Enabled Sensors”, Springer, 2008.
5 Ramon Pallas-Areny, John G. Webster, “Sensors and signal conditioning” John Wiley & Sons, 2001.
6 Aiguo Wu, Waheed S. Khan, “Nanobiosensors: From Design to Applications”, Wiley-VCH Verlag GmbH, 2020

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

4 Vijay.K.Varadan, Linfeng Chen, Sivathanupillai, “Nanotechnology Engineering in Nano and Biomedicine”, John Wiley & Sons, 2010.
5 Vinod Kumar Khanna, “Nanosensors: Physical, Chemical, and Biological”, Publisher: CRC Press,2021
6 Jerome Schultz, Milan Mrksich, Sangeeta N. Bhatia, David J. Brady, Antonio J. Ricco, David R. Walt, Charles L. Wilkins, “Biosensing: International Research and Development”, Springer, 2006

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1. Explain the physical effects involved in signal transduction of sensors.
2. Write a short note on inorganic nanosensors.
3. Describe general configuration and basic principle of biosensors
4. Explain different classes of materials for biosensors.

Semester IV	
Elective Course	
Course Code: **MSNST04DSE15**	Course Name: **Nanorobotics**

Course Description
The course introduces the basic concepts of fabrication, challenges and applications in the field of nanorobotics. Principles and manipulation of nanostructures advantageous for the fabrication of functional nanobots are covered. Basic understanding of diverse application fields of nanorobots are also included.

Course Objectives

1. To learn the basic concepts of principles, procedures and considerations in nanorobotics
2. To study the properties of different nanomaterials for being used in nanorobotics
3. To understand the challenges associated with the development of nanorobotics and ways to address them
4. To understand the application fields of nanobots

Credit			Teaching Hours			Assessment		
L/T	**P/I**	**Total**	**L/T**	**P/I**	**Total**	**CE**	**ESE**	**Total**
3	0	3	54	0	54	40	60	100

L/T: Lecture/ Tutorial; P/I: Practical/Internship; CE: Continuous Evaluation, ESE: End Semester Evaluation

Course outcomes

Course Learning Outcomes: At the end of the course, the student will be able to –

C01	Explain the most common application areas of nanorobots
C02	Analyze the properties of nanomaterials for fabrication of specific nanobots
C03	List the challenges associated with design of nanobots and the ways to address them
C04	Explain how nanomaterials can be manipulated for robot applications

Course outcomes based on revised Blooms taxonomy

Module	Course Contents	No. of Hrs
1.0	**Introduction to Nanorobotics**	**13**

1.1	Introduction to Nanorobotics, Research History, Milestones, Future perspectives, opportunities and challenges	
1.2	Different types of nanorobots, application areas, challenges, Grey goo	
1.3	Market niche and Global scenario of nanorobotics	
Suggested Reading Specific to the module		
1.1	Nanorobotics: Current Approaches and Techniques, Springer Newyork, Constantinos Mavroidis, Antoine Ferreira, 2013	
1.2	M. Sitti, "Micro- and Nano-Scale Robotics", Proceedings of the 2004 American Control Conference, Massachusetts, June 30 -July 2, 2004, pp 1-8 (2004)	
1.3	Nanorobotics: Current Approaches and Techniques, Springer Newyork, Constantinos Mavroidis, Antoine Ferreira, 2013	
2.0	**Molecules and structures in nanorobotics**	**14**
2.1	Nanostructures useful in nanorobotics- carbon nanotubes for nanotweezers, nanojoints, linear bearings and other nanomanipulations, fullerenes	
2.2	Supramolecular structures in nano and molecular machinary: rotaxanes, catenanes etc	
2.3	Different nanomachines: nanoshuttles, nanoturnstiles, nanorotors, nanoswitches, nanogears, naoratchets, nanocars, nanoswimmers etc	
2.4	Molecular motor Type-I, Molecular motor Type-II, molecular elevators, Modified molecular motors, molecular pedals, molecular scissors	
Suggested Reading Specific to the module		
2.1	Hertel, T., Martel, R., Avouris, P., 1998, "Manipulation of individual carbon nanotubes and their interaction with surfaces," Journal of Physical Chemistry B, Vol. 102, pp.910-915.	
2.2	Molecular Devices and Machines: A Journey Into the Nanoworld, Wiley, Vincenzo Balzani, Margherita Venturi, Alberto Credi 2013	
2.3	Molecular Devices and Machines: A Journey Into the Nanoworld, Wiley, Vincenzo Balzani, Margherita Venturi, Alberto Credi 2013	
2.4	Molecules at Work: Selfassembly, Nanomaterials, Molecular machinery, Wiley,	

	Bruno Pignataro · 2012	
3.0	**Issues and Challenges**	**13**
3.1	Challenges associated with the development of nanobots: High surface area and related surface phenomenon, Motion of nanosized entities	
3.2	Viscosity in nanodomains, Friction due to miniaturization, Non rigidity, Low inertia in nanodomains, Peclect number	
3.3	Challenges associated with powering the bots, biocompatability and toxicity, application specific challenges	
Suggested Reading Specific to the module		
3.1	Nanorobotics: Current Approaches and Techniques, Springer New York, Constantinos Mavroidis, Antoine Ferreira, 2013	
3.2	Sharma, N. N., & Mittal, R. K. (2008). Nanorobot movement: Challenges and biologically inspired solutions. International journal on smart sensing and intelligent systems, 1(1), 87.	
3.3	Nanorobotics: Current Approaches and Techniques, Springer Newyork, Constantinos Mavroidis, Antoine Ferreira, 2013	
4.0	**Fabrication of nanorobots**	**14**
4.1	Manipulation of Nanoparticles: Manipulation using SPM, TEM, SEM etc, CNTs, manipulation of biological materials, DNA origami, Nanoscale gripping	
4.2	Joining nanostructures- nanosoldering, nanowelding, nanogluing, Sintering, Chemical bonding	
4.3	Cutting nanostructues: Mechanical cutting, Laser ablation	
4.4	Functional nanobot prototypes, Application areas- medicine, dentistry, diagnosis, Surgery, Gene therapy, Sensors, Environmental remediation	
Suggested Reading Specific to the module		
4.1	Atomic Force Microscopy Based Nanorobotics, Modelling, Simulation, Setup Building and Experiments, Springer Berlin Heidelberg, Hui Xie, Cagdas Onal, Stéphane Régnier, Metin Sitti, 2011	
4.2	Sierra, D. P., Weir, N. A., & Jones, J. F. (2005). A review of research in the field	

	of nanorobotics, Molhave, K., Madsen, D. N., Dohn, S., Boggild, P., 2004, "Constructing, connecting and soldering nanostructures by environmental electron beam deposition," Nanotechnology, Vol. 15, pp. 1047-1053.
4.3	Sierra, D. P., Weir, N. A., & Jones, J. F. (2005). A review of research in the field of nanorobotics.
4.4	Nanorobotics: Intelligent Drug Delivery Using Biohybrid, Fouad Sabry, 2022

Core Compulsory Readings (Books, Journals, E-sources Websites/ weblinks) List

1 Nanorobotics: Current Approaches and Techniques, Springer Newyork, Constantinos Mavroidis, Antoine Ferreira, 2013

2 Molecular Devices and Machines: A Journey Into the Nanoworld, Wiley, Vincenzo Balzani, Margherita Venturi, Alberto Credi 2013

3 Molecules at Work: Selfassembly, Nanomaterials, Molecular machinery, Wiley, Bruno Pignataro · 2012

4 Atomic Force Microscopy Based Nanorobotics, Modelling, Simulation, Setup Building and Experiments, Springer Berlin Heidelberg, Hui Xie, Cagdas Onal, Stéphane Régnier, Metin Sitti, 2011

5 Sierra, D. P., Weir, N. A., & Jones, J. F. (2005). A review of research in the field of nanorobotics.

Core Suggested Readings (Books, Journals, E-sources Websites/ weblinks) List

4 Nanorobotics: Intelligent Drug Delivery Using Biohybrid, Fouad Sabry, 2022

5 "Constructing, connecting and soldering nanostructures by environmental electron beam deposition," Nanotechnology, Vol. 15, pp. 1047-1053.

6 Hertel, T., Martel, R., Avouris, P., 1998, "Manipulation of individual carbon nanotubes and their interaction with surfaces," Journal of Physical Chemistry B, Vol. 102, pp.910-915.

TEACHING LEARNING STRATEGIES

- Assignments, Internal examinations, Seminars, Semester Viva Voce

MODE OF TRANSACTION

- Off-line mode, Black Board and Chalk

ASSESSMENT RUBRICS

	Marks
End Semester Evaluation	60%
Continuous Evaluation	40%

Sample Questions to test Outcomes.

1. Write a note on the applications of nanorobots in gene therapy?
2. How low inertia in the nano-domains would affect the design of nanorobots?
3. How can you use CNTs as nanotweezers?
4. Explain the design of a nanocar based on fullerene?
5. Give a note on nanobots being used for environmental remediation?