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GURU GOBIND SINGH INDRAPRASTHA UNIVERSITY

TWENTY SEVENTH MEETING

OF THE

ACADEMIC COUNCIL

DATE	:	15.06.2009
TIME	:	12:00 Noon
VENUE	:	CONFERENCE ROOM

MINUTES

KASHMERE GATE, DELHI-110403

TWENTY SEVENTH MEETING OF THE ACADEMIC COUNCIL HELD ON 15.06.2009 at 12:00 Noon

INDEX OF AGENDA ITEMS

Agenda Item No.27.9 :- **To report modifications made in the Scheme of Examinations and Syllabi of Ist, IInd & IIIrd Semesters of M.Tech. (Nano Science & Technology).**

The Council noted the modifications made in the Scheme of Examinations and Syllabi of Ist, IInd & IIIrd Semesters of M.Tech. (Nano Science & Technology) as approved by the Vice-Chancellor on April 28, 2009 on the recommendations of the Sub-Committee of the Academic Council made in its meeting held on January 28, 2009 under the Chairmanship of Director-Academic Affairs.

Agenda Item No.27.10 :- **To report about the revision of Syllabi of HS 101 (Communication Skill 1) and HS 102 (Communication Skill 2) offered by University School of Humanities and Social Sciences to 1st and 2nd Semester Students of USIT & USCT.**

The Council noted the revision of Syllabi of HS 101 (Communication Skill 1) and HS 102 (Communication Skill 2) offered by University School of Humanities and Social Sciences belonging to 1st and 2nd Semester Students of USIT & USCT as approved by the Vice-Chancellor on the recommendations of the Sub-Committee of the Academic Council made in its meeting held on May 27, 2009 under the Chairmanship of Director-Academic Affairs.

Scheme of Examination

&

Syllabus

of

Master of Technology

in

Nano Science & Technology

w.e.f Academic Year 2009

University School of Basic & Applied Sciences
Guru Gobind Singh Indraprastha University
Sector 16C, Dwarka, Delhi 110078

Entrepreneurship | Employability | Skill Development

Approved in 27th Meeting of the Academic Council held on 15-06-2009. Agenda Item No. 27.9

Scheme of Examination of M.Tech. Nano Science & Technology

Programme Specific Objectives (PSOs)

PSO1. Students with diverse educational backgrounds are converged to a common stream of nanoscience and nanotechnology.

PSO2. Programme focuses on strengthening the fundamentals of physical and chemical sciences and gradually transcends towards the application aspects of this fast growing and intriguing field.

PSO3. The laboratories are designed to strengthen the experimental skills of the students on synthesis & fabrication of nanomaterials, study some of their important properties and to provide the students hands on training on the equipments.

PSO4. The students are encouraged towards self-learning, literature survey, designing experiments and carrying out projects under close guidance of faculties.

Programme Outcomes (POs)

PO1. Students develop the essential skill sets for synthesizing, studying and applying the nanomaterials to meaningful practical purposes and develop useful devices.

PO2. Extensive interaction with the faculties and exhaustive discussions/ presentations throughout the course of the programme aids the students towards critical thinking and enhances their overall presentation &communication skills.

PO3. Summer training, minor & major projects in other research institutes and universities expose the students to various research environments enabling them for future research & opening placement avenues.

PO4. After completion of the programme our students will not only be "Research Ready" for industries and academia but also will be adequately sensitized towards society and environment.

Mapping between PSOs and POs
(on a scale of 1-10, with 10 excellent)

	PSO_1	PSO_2	PSO_3	PSO_4
PO_1	8	8	8	8
PO_2	8	8	8	8
PO_3	9	8	9	8
PO_4	8	8	9	9

Semester - I Credit: 27

S. No.	Course Code	Title of the course	Credits	Remarks L/T/P
1.	NST-101	Elements of Physics	4	4/0/0
2.	NST-103	Elements of Physical Chemistry	4	4/0/0
3.	NST-105	Nanoparticles and Microorganisms, Bionanocomposites	3	3/0/0
4.	NST-107	Elements of Material Science and properties of Nanomaterials	4	4/0/0
5.	NST-109	Nanotechnology & Society	1	1/0/0 (NUES)
6.	NST-111	Basic Mathematics / Life Sciences	2	2/0/0
7.	NST-151	Laboratory-I	6	0/0/12
8.	NST-153	Self Study-I	3	0/3/0

L = Lecture, T = Tutorial, P = Practical

NUES =>Non University Examination System

Semester - II Credit: 29

S. No.	Course Code	Title of the course	Credits	Remarks L/T/P
1.	NST-102	Fabrication techniques and Characterisation of Nanomaterials	4	4/0/0
2.	NST-104	Soft Synthetic Routes & Some Novel Nanomaterials	4	4/0/0
3.	NST-106	Nanodevices & Nanosensors	4	4/0/0
4.	NST-108	Scientific Computation & Simulation	1	1/0/0 (NUES)
5.	NST-110	Solutions & Surface Phenomenon	4	4/0/0
6.	NST-112	Business Enterprise in Nanotechnology & Project Management	1	1/0/0 (NUES)
7.	NST-152	Laboratory-II	6	0/0/12
8.	NST-154	Self Study-II	3	0/3/0
9.	NST-156	Scientific Computation & Simulation	2	0/0/4

NUES =>Non University Examination System

The students will proceed for Summer Training at the end of second semester for a periodof 6-8 weeks. The students will then submit the training report after its completion to the program coordinator.

Semester - III Credit: 24

S. No.	Course Code	Title of the course	Credit /wk	Remarks L/T/P
1.	NST-201	Advanced Nanomaterials	3	3/0/0
2.	NST-203	Semiconductor nanostructures and nanoparticles	3	3/0/0
3	**Electives (any 2)**			
	NST-205	Molecular Nanoelectronics	3	3/0/0
	NST-207	Photonics &Plasmonics	3	3/0/0
	NST-209	Carbon Nanotubes &Functionalisation	3	3/0/0
	NST-211	Computational Nanoscience	3	3/0/0
	NST-215#	Nanocomposites	3	3/0/0
4	NST-213	IPR& Nanotechnology	1	1/0/0 (NUES)
5	NST-251	Self Study-III	2	0/2/0
6	NST-253	Minor Project	5	-
7	NST-255	Summer training (Viva-voce)	4	-

NUES =>Non University Examination System

Paper code approved in the BOS meeting of the USBAS held on 22.09.2016

Semester - IV Credit: 25

S. NO.	Course Code	Title of the course	Credit /wk	Remarks
1.	NST-202	Project Work /Internship (Seminar)	20	**
2.	NST-204	Comprehensive Viva Voce	5	NUES

NUES =>Non University Examination System

Total Credits: 105

Credits Required for the Degree: 100

Course Code: NST-101 **Title: Elements of Physics**

L/T/P: 4/0/0

CO_1	To develop familiarity with the physical concepts and the mathematical methods of quantum mechanics.
CO_2	To understand the concepts of concepts of spin and angular momentum, as well as their quantization and addition rules and application of quantum mechanics to physical situations.
CO_3	To understand the various aspects of Approximate methods in quantum mechanics, time independent and time dependent perturbation theory.
CO_4	To understand the introductory concepts of statistical mechanics and both the classical and the quantum regime of statistical mechanics. The description of quantum statistics is nonmathematical in this course.

Unit-I: Introduction to Quantum Mechanics: Wave-particle duality, Schrödinger equation and expectation values, Uncertainty principle. Solutions of the one-dimensional Schrodinger equation for free particle, particle in a box, particle in a finite well, linear harmonic oscillator. Reflection and transmission by a potential step and by a rectangular barrier.

Unit-II: Solution of Time independent Schrödinger equation at higher dimensions and more complicated systems Particle in a three dimensional box, linear harmonic oscillator and its solution, density of states, free electron theory of metals. The angular momentum problem. The spin half problem and properties of Pauli spin matrices.

Unit-III Approximate methods, Time independent and time dependent perturbation theory for non-degenerate and degenerate energy levels, the variational method, WKB approximation, adiabatic approximation, sudden approximation

Unit-IV: Statistical Mechanics, Microstates and entropy and its statistical definition, Entropy of mixing, Gibb's free energy, Gibb's paradox, phase space density, ergodic hypothesis, Liouville's theorem, The microcanonical-, canonical- and grand canonical- ensemble and their connections, Fluctuations. Classical Statistical systems, Boltzman statistics Liouville's theorem, Themicrocanonical-, canonical- and grand canonical- ensemble and their connections, Fluctuations. Classical Statistical systems, Boltzman statistics and quantum statistical systems, Fermi-Dirac and Bose-Einstein Statistics and their applications (An overview).

References: (NST 101)

1. Quantum Physics – A. Ghatak
2. Quantum Mechanics-Mc Quarie
3. Quantum Mechanics - Bransden and Joachen
4. Quantum Mechanics - Vol 1&2 - Cohen-Tannoudji
5. Quantum wells, Wires & Dots,: Theoretical & Computational Physics of Semiconductors Nano-stuructures, Paul Harrison
6. Quantum Hetero-structures: Micro-electronics and opto-electronics, V V Mitin, VA Kochelap, MA Stroscio.
7. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, 2^{nd} Edition by Eisberg, Robert; Resnick, Robert

8. Principles of Quantum Mechanics 2nd ed. - R. Shankar
9. Thermodynamics and Statistical Mechanics - A N Tikhonov, Peter T Landberg, Peter Theodore Landsberg
10. Thermodynamics and Statistical Mechanics by John M. Seddon , J. D. Gale
11. Statistical Physics by K. Huang
12. Statistical Mechanics-Landau &Lifshitz
13. Statistical Mechanics – Sonntag.
14. Statistical Mechanics – Mc Le Leland

Course Expected Outcomes:

CEO_1	The students will be able to formulate and solve physics problems using quantum mechanics.
CEO_2	The students will be able to grasp the concepts of spin and angular momentum, as well as their quantization and addition rules.
CEO_3	The students will be able to grasp the various aspects of Approximate methods in quantum mechanics, time independent and time dependent perturbation theory.
CEO_4	The students will be able to delve into elementary classical statistics so that they can describe equilibrium systems. The students will also have idea of ensembles, classical and quantum statistics and their applications.

Course Code: NST-103 **Title: Elements of Physical Chemistry**

L/T/P: 4/0/0

Course Objectives:

CO_1	The purpose of this paper is to provide the students an overview of the important concepts of physical chemistry. Enabling the students to understand and appreciate the significance of the basic tools.
CO_2	Thermodynamics and its application in phase rule are central to understand a large number of related applications. The emphasis here is to strengthen these concepts.
CO_3	The concepts of electrochemistry, chemical kinetics and photochemistry are fundamental and useful in understanding the processes involved in optical devices, smart coatings, electrochemical sensors, etc..
CO_4	For making any advances in high end materials, material science lies at the core keeping this in consideration, this paper also covers a detailed unit on diffusion in solids.

Unit I- Chemical Bonding: Atomic Bonding in solids, Types of bond: Metallic, Ionic, Covalent and vanderwaals bond; Hybridisation; H- bonding Molecular orbital theory for simple molecules such as diatomic molecule etc.
Types of Material: Metals, Semiconductors, Composite materials, Ceramics, Alloys, Polymers.

Unit II- Overview to Thermodynamics: The first and second laws of thermodynamics. Thermodynamic functions, heat capacity, enthalpy, entropy. Phase equilibrium in one component system, real gases, the interactions between gases.Ehrenfest classification of phase transition,the physical liquid surface; surface tension, curved surfaces, capillary action.
Theory of Solution and related topics: Liquid mixtures: free energy as a function of composition, ideal solutions and excess functions.
Equilibrium Electrochemistry; electrochemical cells, Methods for calculation of thermodynamic equilibrium. Electrochemical processes.

Unit III- Diffusion-Fick's Law, mechanisms of diffusion; generation of point defects; self-diffusion; the influence of the pressure and pressure gradient; Kirkendall effect; fast diffusion; influence of isotropic state; experimental methods of investigation of diffusion.

Unit IV- Reaction Kinetics and Photochemistry: Zero, First & Second order reactions. Dependence of ***k*** on Temperature.An overview of collision and activated complex theory. Steady State approximation.
Laws of Photochemistry, Fluorescence, Phosphorescence, Chemiluminescence, Jablonski diagram and quenching, Photochemistry of nanomaterials.

References: (NST 103)

1. Physical Chemistry, 1st Edition –Ball.
2. Thermodynamics-Glasston.
3. Principals of Physical Chemistry-Marron-Pruton.
4. Advanced Physical Chemistry – Atkins Peter, Paula Julio

Approved in 27th Meeting of the Academic Council held on 15-06-2009. Agenda Item No. 27.9

5. Inorganic chemistry-Cotton-Wilkinson.
6. Introduction to Theoretical Chemistry – Jack Simons.

Course Expected Outcomes:

CEO_1	The student should be able to acquire a detailed understanding of the structure and interactions of atoms and molecules that are essential to understand the complex behaviour of matter and hence nanomaterials around us.
CEO_2	The students should be able to apply the concepts of Thermodynamics, Phase Equilibrium, Solution Thermodynamics, Kinetics and photochemistry to design systems and preparation of materials with desirable properties via most efficient routes.
CEO_3	Diffusion of solids in an extremely important phenomenon to obtain desired properties in materials. Control of factors influencing diffusion in solids will equip the students with this important phenomenon.
CEO_4	This paper will give the students a strong fundamental grasp over all these important concepts of physical chemistry, which they should be able to apply when dealing with real life systems.

Course Code NST-105 **Title: Nanoparticles & Micro-organisms Bionanocomposites**

L/T/P: 3/0/0

Course Objectives:

CO_1	To enable students to be competent in biological methods of nanoparticle preparation
CO_2	To enable the students to understand the role of microorganism for toxicity detection of nanomaterials
CO_3	To enable the students to understand natural nanocomposites with a view to understand nanocomposites for bone and teeth replacement
CO_4	To enable the students to learn about Nanobio Systems

Unit – I Biological Methods of Synthesis:Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Synthesis process and application, Role of plants in nanoparticle synthesis

UNIT – II Microorganisms for synthesis of nanomaterials and for toxicity detection
Natural and artificial synthesis of nanoparticles in microorganisms; Use of microorganisms for nanostructure formation, Testing of environmental toxic effect of nanoparticles using microorganisms;

Unit – III Nanocomposite biomaterials, teeth and bone substitution,Natural nanocomposite systems as spider silk, bones, shells; organic-inorganic nanocomposite formation through self-assembly. Biomimetic synthesis of nanocomposite material; Use of synthetic nanocomposites for bone, teeth replacement.

Unit – IV Nanobio Systems**,** Nanoparticle-biomaterial hybrid systems for bioelectronic devices, Bioelectronic systems based on nanoparticle-enzyme hybrids; nanoparticle based bioelectronics biorecognition events. Biomaterial nanocircuitry; Protein based nanocircuitry; Neurons for network formation. DNA nanostructures for mechanics and computing and DNA based computation; DNA based nanomechanical devices. Biosensor and Biochips.

References: (NST 105)

1. Nanobiotechnology: Concepts, Applications and Perspectives, Editors: C.M. Niemeyer, C.A. Mirkin, Wiley-VCH, ISBN: 978-3-527-30658-9
2. Bionanotechnology: Lessons from Natureby David S. Goodsell, Wiley,ISBN: 978-0-471-41719-4
3. Introduction to Nanotechnology, Authors: R. Singh, S. M. Gupta, Oxford University Press, ISBN:9780199456789
4. Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology- Hari Singh Nalwa, American Scientific Publishers, ISBN: 1-58883-004-7

Course Expected Outcomes:

CEO_1	The students will learn the biological methods of nanoparticle synthesis which help them to be able to synthesize nanoparticles in a green way in laboratory/industry.
CEO_2	The students understand toxicity issues related to the use of nanomaterials and the role of microorganisms in assessing them
CEO_3	The students will study the properties of natural nanocomposite systems, which is helpful in taking inspiration and producing products having superior properties using greener techniques
CEO_4	The students will understand some nanoparticle-biomaterial hybrid systems which helps them to design hybrid systems for bioelectronic devices, computing and nanomechanical devices etc.

Course Code: NST-107 **Title: Elements of Material Science and Properties of Nanomaterials**

L/T/P: 4/0/0

Course Objectives:

CO_1	To provide students understanding of the crystal structures and importance of defects in materials.
CO_2	To enable the students to understand the electronic properties of materials.
CO_3	To understand the basics of electron transport in nanostructures and dielectric properties of materials.
CO_4	To enable the students to understand the optical properties of nanomaterials.

Unit-I Solid State Physics (Overview): Amorphous, crystalline, crystals, polycrystals, symmetry, Unit Cells, Crystal Structures (Bravais Lattices), , Crystallographic Directions, Crystallographic Planes, Miller Indices, Bragg's Law, X-ray Diffraction.
Imperfections of crystal structure: point defects, Grain boundaries, phase boundaries, Dislocations Screw, Edge and Mixed Dislocations generation of defects by quenching, by plastic deformation and by radiation, interaction between point defects and dislocations

Unit-II Electronic Properties, Classification of materials: Metal, Semiconductor, Insulator, Band structures, Brillouin zones, Mobility, Resistivity, Relaxation time, Recombination centers, Hall effects.

Unit –III Confinement and transport in nanostructure, Current, reservoirs, and electron channels, conductance formula for nanostructures, quantized conductance. Local density of states. Ballistic transport, Coulomb blockade, Diffusive transport, Fock space.
Dielectric properties: Polarisation, Ferroelectric behaviour.

Unit-IV Optical Properties, Photoconductivity, Optical absorption & transmission, Photoluminescence, Fluorescence, Phosphorescence, Electroluminescence.

References: (NST - 107)

1. Introduction to Solid State Physics -C. Kittel
2. Solid State Physics- A.J. Dekker
3. Solid State Physics -R.K Puri and V.K.Babar
4. The Physics and Chemistry of Solids - Stephen Elliott & S. R. Elliott
5. Scanning Probe Microscopy: Analytical Methods (NanoScience and Technology)- Roland Wiesendanger
6. Advanced X-ray Techniques in Research and Industries - A. K. Singh (Editor)
7. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition - Harold P. Klug, Leroy E. Alexander
8. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)**-** David B. Williams and C. Barry Carter

9. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton
10. Structures and Properties of Solid State Materials – B. Viswanathan.
11. Basic Solid State Chemistry – Anthony R. West.

Course Expected Outcomes:

CEO_1	The students will be able to describe the crystal structures and defects in the different classes of materials.
CEO_2	This will strengthen their fundamental understanding of the electronic properties of materials.
CEO_3	The students will have a good understanding of electron transport in nanostructures and the dielectric properties of materials.
CEO_4	The students will have good fundamental grasp over the optical properties of nanomaterials.

Course Code: NST-109 **Title: Nanoscience & Society**

L/T/P: 1/0/0

(NUES)

Course Objectives:

CO_1	To enable students to learn the basic goals of Nanoscience and Nanotechnology which may be applied in their usage.
CO_2	To enable the students to link Nanoscience and Nanotechnology with Society which creates an understanding of its applications and impact on us.
CO_3	To enable the students to analyse case studies of research ethics and place development activities into wider ethical regimes

Introduction to Societal Implications of Nanoscience and Nanotechnology, Nanotechnology Goals: Knowledge and scientific understanding of nature, Industrial manufacturing, materials and products, Medicine and the human body, Sustainability: Agriculture, water, energy, materials and clean environment, Space exploration, National security. Moving into the Market.

References: (NST - 109)

1. Concept Document “Nanoscience & Technology Initiative” of DST, GOI, New Delhi, 2002.
2. Winner, Langdon, “Societal Implications of Nanotechnology”, Testimony to ---- on science of the US House of Representatives, 2003.
3. Ethics in Engineering, M.Martin& R. Schinzinger, 4th edition, McGraw-Hill[0-07-283115-4];
4. Nanotechnology Regulation and Policy Worldwide (Artech House), Jeffrey H. Matsuura 2006.

Course Expected Outcomes:

CEO_1	The students will learn the basic role and goals of Nanoscience and Nanotechnology which help them to tap their full potential.
CEO_2	The students will be able to know the applications of Nanoscience and Nanotechnology in important fields.
CEO_3	The students will understand ethical issues related to nanotechnology products and applications.

Course Code: NST-111 **Title: Life Sciences**

L/T/P: 2/0/0 **2 Credits**

Course Objectives:

CO_1	The course is designed to impart basic knowledge of the Life science and its components.
CO_2	The main objective of incorporating Life Sciences in the first semester of M.Tech (NST) course is to bridge the gap between subjects studied at the qualifying degree level by the students who join this course from non-bio backgrounds.

Contents:

UNIT I
1. Exploring Life
2. The evolutionary history of biological diversity
3. Brief classification of living kingdoms
4. Difference between prokaryotes and eukaryotes
5. Plants and animal diversity ; Five kingdoms- Monera, Protista, Fungi, Plantae, Animalia ; Three domains- Bacteria, Archaea and Eukarya

UNIT II
6. General structure of Bacteria, Archaea and Eukarya – Bacteria, Viruses, Fungi and Actinomycetes.
Mechanism of exchange of materials with the environment, ecological roles.

UNIT III

7. Chemistry of Life : The structure and function of biological molecules of life-basic structure, composition and function of carbohydrates, proteins, lipids, nucleic acids and enzymes.

UNIT IV

8. Integrated control systems; Nervous system and endocrine system

UNIT V
9. Natural synthesis of some biological materials; Their composition and properties- Teeth, Bone, silk etc.

Course ExpectedOutcomes :

CO_1	Life Science course will provide necessary information and knowledge about the various aspects of Life science, living organisms and biodiversity.
CO_2	The students coming from non-bio background will find a smooth transition to understand the Nano-bio part of the M.Tech (NST) course.

Approved in 27th Meeting of the Academic Council held on 15-06-2009. Agenda Item No. 27.9

Course Code : NST 113 **Title: Basic Mathematics**

L/T/P : 2/0/0 Credits–2

Course Objectives:

CO_1	The main objective of incorporating Basic Mathematics in the first semester of M.Tech. (NST) course is to bridge the gap between subjects studied at the qualifying degree level by the students who join this course from multi-disciplinary backgrounds.
CO_2	The students will be familiar with calculus of functions of one variable and differential equation of first order.
CO_3	The students will be familiar with linear algebra.

Course Contents:

UNIT – I (Successive Differentiation)

Higher order derivatives; the nth derivatives of some important functions; Lebnitz's Theorem.

UNIT-II (Integration of Trigonometric Functions)

Reduction formula and evaluation of $\int_0^{\pi/2} sin^m x\, dx$; $\int_0^{\pi/2} cos^m x\, dx$; $\int_0^{\pi/2} sin^m x\, cos^n x\, dx$, m and n being positive integers; Integral of the form $\int R(cosx, sinx)\, dx$,R being a rational function of $cosx$ and $sinx$; Integral of the form $\int \frac{acosx + bsinx + c}{Acosx + Bsinx + C} dx$; definite integrals.

UNIT-III (Differential Equations of First Order)

Differential Equation; differential equations of first order and first degree; Methods of solving differential equations of the form $\frac{dy}{dx} = \frac{f(x,y)}{g(x,y)}$; Linear differential equations of first order.

UNIT-IV (Linear Algebra)

Rank of a matrix, solution of Linear system of equations, consistency of linear system of equations.

References: (NST-113)

1. Thomas' Calculus, George B. Thomas, Joel Hass, Christopher Heil and Maurice D. Weir Fourteenth Edition, Pearson 2018
2. Introduction to Linear Algebra, Third Edition 3rd Edition, Gilbert Strang,ISBN-13: 978-0961408893, ISBN-10: 0961408898
3. Differential Equations, Shepley L. Ross, Wiley India, 2004, ISBN-978-81-265-1537-0

Course Expected Outcomes:

CEO_1	The students who did not study mathematics at the undergraduate level are expected to gain sufficient expertise and overall view of important mathematical techniques that make them equipped for smooth understanding of various Physical Science papers that are an integral part of this course in the following semesters.
CEO_2	Students will be able to solve problems related calculus of functions of one variable and differential equations problem of first order analytically.
CEO_3	Students will be able to solve problems related to linear algebraic system of equations.

Course Code: NST-151 **Title: Laboratory-I**

L/T/P: 0:0:12 6Credits

Course Objectives:

CO_1	The objective is to bring students from various streams to a common point by real time hands-on practicals, so that they come to understand simple underlying physical and chemical principles. The experiments designed are simple and the students are expected to observe and learn.
CO_2	**Section A:** This lab particularly touches upon some fundamental concepts of experimental physical chemistry, which are important in understanding and interpreting more complex phenomena. **Section B:** This paper focuses on enabling students to synthesize nanomaterials by different physical and chemical methods.
CO_3	The students will undergo hands-on training on various equipment for synthesizing and characterizing nanomaterials.
CO_4	They also learn detailed writing, data analysis and discussion of results. This is the first step towards developing a research oriented mindset.

Section A

1. To study kinetics of hydrolysis of an ester.
2. Effect of surfactant concentration on equivalent conductance and determination of critical micelle concentration (CMC).
3. Verification of Lambert Beer' slaw and determination of concentration of unknown solution by UV-visible spectrophotometer.
4. Preparation of colloidal silver nano particles with trisodiumcitrate and their characterization by UV-visible spectroscopy.
5. To study Hydrogen bonding by FTIR spectroscopy
6. Preparation of metal oxide nano particles by micro emulsion technique.
7. Characterization of prepared metal oxide nano particles by XRD and determination of their size using Scherrer's formula.

Section B

1. Synthesis of zinc oxide nano particles by precipitation method and characterize using UV-visible absorption spectroscopy and X-ray diffraction
2. Synthesis of Mn doped zinc oxide nanoparticles and characterize using UV-visible absorption spectroscopy and X-ray diffraction
3. Synthesis of copper oxide nano particles by precipitation method and characterize using dynamic light scattering and Raman spectroscopy
4. Synthesis of nickel oxide nano particles by precipitation method and determine the average size of nano particles using dynamic light scattering and crystallite size using X-ray diffraction
5. Synthesis of Fe_3O_4 nano particles and characterize using X-ray diffraction and Raman spectroscopy
6. Synthesis and characterization of cobalt ferrite nano particles using X-ray diffraction and Raman spectroscopy.

Course Expected Outcomes:

CEO_1	Students from various backgrounds are expected in the course. After the first semester, they will develop a feel about the common tools used in real life nanoscience work such as DLS, XRD, FTIR, UV-Vis spectroscopy to name a few. They will start developing and consolidating simple ideas from Chemistry, needed to go forward.
CEO_2	They will learn various chemical techniques involved in synthesis of nanomaterials.
CEO_3	They will learn to study some fundamental physical parameters such as bandgap, particle size determination, identification of hydrodynamic radius, fingerprinting with UV-Vis-NIR, FTIR and XRD.
CEO_4	They will be become verse with report writing, data analysis and discussion of results.

Course Code: NST-153 **Title: Self Study-I**

L/P/T: 0/3/0 3 Credits

Course Objectives:

CO_1	To bring the student's focus on the core area of Nanoscience &Technology, relevant topics from the field are assigned to the students for presentations. These topics are decided by the faculties and are usually those that are not taught in details in various papers but are of immense importance.
CO_2	Students learn to look for useful literature under close guidance of the faculties.
CO_3	Enables the students to develop effective presentation skills
CO_4	Detailed discussions and Q/A session during each presentation provides the students an elementary flavour of the subject and gears them up for a more rigorous training for future.

Course Contents:

Presentations will be made by the students on relevant topics assigned and supervised by the faculty. The presentations will be subjected to internal and external evaluations.

Course Expected Outcomes:

CEO_1	The students will learn how to effectively search, learn and present with a proper representation.
CEO_2	By mutual interaction, the students will learn to widen their horizon of knowledge in the field of nanoscience and technology. Not only they will learn to present, but also they learn to question and discuss.
CEO_3	The students will develop effective presentation skills.
CEO_4	The students will gear up for a more rigorous training.

Course Code : NST 102 Title: Fabrication Techniques and Characterisation of Nanomaterials

L/T/P : 4/0/0 Credits– 04

Course Objectives:

CO_1	To give students proper exposure to various methods for synthesis of nanomaterials, needed for fabrication of various nanodevices.
CO_2	To know in depth different characterization techniques for characterizing the nanostructures.
CO_3	Application of optical methods for studying nanostructures.
CO_4	Different lithographic techniques and nanomanipulation strategies are to be discussed for fabrication of Nano materials & devices.

Course Contents:

Unit – I Fabrication of Nanomaterials by Physical Methods: -Inert gas condensation, Arc discharge, RF-plasma, Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy, Chemical vapour deposition method and Electro deposition.

Unit – II Scanning Electron Microscopy (SEM), Scanning Probe Microscopy (SPM), TEM and EDAX analysis, X-ray diffraction

Unit – III Optical Microscope and their description, operational principle and application for analysis of nanomaterials, UV-VIS-IR Spectrophotometers, Principle of operation and application for band gap measurement

Unit – IV M based nanolithography and nano manipulation, E beam lithography and SEM based nanolithography and nano manipulation, Ion beam lithography, oxidation and metallization. Mask and its application. Deep UV lithography, X-ray based lithography.

References: (NST-102)

1. Fabrication of fine pitch gratings by holography, electron beam lithography and nano-imprint lithography (Proceedings Paper) Author(s): Darren Good child; Alexei Bogdanov; Simon Wingar; Bill Benyon; Nak Kim; Frank Shepherd
2. Micro fabrication and Nano manufacturing- Mark James Jackson
3. A Three Beam Approach to TEM Preparation Using In-situ Low Voltage Argon Ion Final Milling in a FIB-SEM Instrument E L Principe, P Gnauck and P Hoffrogge, Microscopy and Microanalysis (2005), 11: 830-831 Cambridge University Press.
4. Processing & properties of structural nano materials - Leon L. Shaw (editor)

Course Expected Outcomes:

CEO_1	The students will have grasp on various methods, and their underlying principles for preparing variety of nanomaterials, some of which they will be doing in the lab.
CEO_2	They will also learn the working principles of various characterization techniques to analysis nanomaterials. They will have hands on training on some of these, during the course of program.
CEO_3	An understanding of optical properties will enable the students to correlate the size/shape of nanomaterials with their electronic structure.
CEO_4	A good knowledge of lithographic techniques will enable them to apply these concepts for designing novel nano devices.

Course Code: NST-104 **Title: Soft Synthetic Routes & Some Novel Nanomaterials**

L/T/P: 4/0/0 **Credits– 04**

Course Objectives:

CO_1	To enable students to learn the Chemical Routes for Synthesis of Nanomaterials
CO_2	To enable students to understand the properties Nanocomposites
CO_3	To enable students to understand the properties Nanopolymers
CO_4	To enable students to understand the properties of Metal Nanoparticles

Unit–I Chemical Routes for Synthesis of Nanomaterials: Chemical precipitation and co-precipitation; Metal nanocrystals by reduction, Sol-gel synthesis; Microemulsions or reverse micelles, myle formation; Solvothermal synthesis; Thermolysis routes, Microwave heating synthesis; Sonochemical synthesis; Electrochemical synthesis; , Photochemical synthesis, Synthesis in supercritical fluids

Unit–II Nanocomposites: An Introduction: Types of Nanocomposite (i.e. metal oxide, ceramic, glass and polymer based); Core-Shell structured nanocomposites Superhard Nanocomposite: Synthesis, applications and milestones.

Unit–III Nanopolymers: Preparation and characterization of diblock Copolymer based nanocomposites, Nanoparticles polymer ensembles; Assembly of polymer-Nanoparticles composite material; Fabrication of polymer-mediated organized Nanoparticles assemblies; Applications of Nanopolymers in Catalysis

Unit–IV Metal Nanoparticles: Size control of metal Nanoparticles and their characterization; Study of their properties: Optical, electronic, magnetic; Surface plasmon band and its application; Role in catalysis, Alloy Nanoparticles, Stabilization in Sol, Glass, and other media, Change of bandgap, Blueshift, Colour change in sol, glass, and composites, Plasmon Resonance.

References: (NST-104)

1. Chemistry of Nanomaterials: Synthesis, Properties and Applications, Editors: CNR Rao, H.C. mult. Achim Müller, A. K. Cheetham, Wiley‐VCH Verlag GmbH & Co. KGaA, ISBN: 9783527306862, 9783527602476.
2. Nanochemistry: A Chemical Approach to Nanomaterials: Edition 2, Authors: Geoffrey A Ozin, André Arsenault, LudovicoCademartiri, Royal Society of Chemistry, Cambridge UK, ISBN: 978-1-84755-895-4, 978-1-78262-626-8.
3. Introduction to Nanotechnology, Authors: R. Singh, S. M. Gupta, Oxford University Press, ISBN:9780199456789
4. Nanocomposite Science and Technology, Editors: P.M. Ajayan, L.S. Schadler, P.V. Braun, Wiley, New York, ISBN: 9783527303595, 9783527602124.
5. The search for novel, superhard materials (Review Article), Stan Veprek, J. Vac. Sci. Technol. A 17(5), 1999, 2401-2420.
6. Block Co-polymers in Nanoscience – Massimo Lazzari, Guojun Liu, SebastienLecommandoux,

Wiley‐VCH Verlag GmbH & Co. KGaA, ISBN: 9783527313099.

Course Expected Outcomes:

CEO_1	The students will learn the chemical methods of nanoparticle synthesis which help them to apply these techniques while carrying out a reaction in a laboratory/industry.
CEO_2	The students will able to understand types, preparation and applications of Nanocomposites, which is very important for their usage modification if needed to get desired product properties.
CEO_3	The students will understand the preparation, characterization and applications of Nanopolymers, which is helpful in their usage and modification if needed to get desired product properties.
CEO_4	The students will learn about the metal nanoparticles, their characterization and application, which are very important for their role as catalysts.

Course Code : NST 106 **Title: Nanodevices & Nanosensors**

L/T/P: 4/0/0 **Credits– 04**

Course Objectives:

CO_1	To provide students understanding of electron transport in nanoscale and the principles of operation of various nanodevices.
CO_2	To enable students, understand the basics of MEMS and NEMS in different applications.
CO_3	To make the student understand how various nanosensors work.
CO_4	To enable student to understand various aspects of nanophotovoltaics, ion -exchange in nanostructure.

Course Contents:

Unit-I Quantum and classical regimes of electron transport, mesoscopic transport. Diffusive transport: Boltzman transport equation, electron mobility and diffusion coefficient, Drift-diffusion model. Quantum electron transport; Double barrier Resonant-Tunneling structures: Coherent tunneling and sequential tunneling, Negative differential resistance, single electron tunneling, Coulomb blockade.

Unit-II Introduction to MEMs / NEMs, Electronic Transport in Nanostructures, Semiconductor devices to Single electron Transistors

Unit-III Nanosensors: Temperature Sensors, Smoke Sensors, Sensors for aerospace and defense: Accelerometer, Pressure Sensor, Night Vision System, Nano tweezers, nano-cutting tools, Integration of sensor with actuators and electronic circuitry Biosensors.

Unit-IV State of Art Ion-beam exchange in Nanostructure material. Nanostructure based Photovoltaic Cells.

References: (NST-106)

1. Sensors: Micro &Nanosensors, Sensor Market trends (Part 1&2) by H. Meixner, Wiley, July 2008ISBN: 978-3-527-62061-6
2. Between Technology & Science: Exploring an emerging field knowledge flows & networking on the nanoscale by Martin S. Meyer. Dissertation.Com. (February 15, 2005); ISBN-10: 1581122535, ISBN-13: 978-1581122534
3. Nanoscience & Technology: Novel structure and phenomena by Ping Sheng (Editor) (2003) CRC Press.
4. Nano Engineering in Science & Technology: An introduction to the world of nano design by Michael Rieth, (2003) World Scientific.
5. Enabling Technology for MEMS and nano devices -Balles, Brand, Fedder, Hierold, (2014) Wiley.
6. Optimal Synthesis Methods for MEMS- G. K. Ananthasuresh (2014) Springer ISBN-10: 1461351014;ISBN-13: 978-1461351016.

7. MEMS & MOEMS Technology and Applications- P. Rai Choudhury; (December 2000); ISBN: 9780819495983
8. Processing Technologies- Gandhi
9. Quantum Transport: Atom to Transistor- SupriyoDatta, Cambridge University Press, 2005.

Course Expected Outcomes:

CEO_1	The students will be able to understand the basics of electron transport in nanostructures, the theory and working of various nanodevices for applications in nanoelectronics.
CEO_2	The students will be able to understand the basics of MEMS/ NEMS and integration of their components for different applications.
CEO_3	The students will be able to understand the basics of nanosensors and their applications.
CEO_4	The students will be able to understand fundamentals of various aspects of operation, design principles, advantage and disadvantages of nanophotovoltaics.

Course Code: NST-108 **Title: Scientific Computation & Simulation**

L/T/P: 1/0/0 Credits- 1 (NUES)

Course Objectives :

CO_1	Introduce the students from diverse backgrounds to the importance of computational techniques and to expand their mathematical skills in areas of numerical methods.
CO_2	Introduce and train students in computational methods with MATLAB as the programming language
CO_3	Expose students to introductory topics and the basics of numerical techniques and programming. Problems are selected from a list which is updated from time to time in tune with the needs of industry/research and topical subjects.
CO_4	Educate students to learn the logic behind solving problems related to real physical examples, simulation, modelling and designing the algorithms and translating them into programmes

Unit-I Computational physics in Science & Technology, brief introduction to the Linux operating system; A review of the numerical techniques (Interpolations, differentiation, integration; Nonlinear equations, the bisection methods, Newton's method, root finding; Differential equations, Euler's method, the Runge-Kutta method; Matrices-inverting, finding eigenvalues and eigenfunctions, etc.).

Unit-II Simple problems based on section –I Using Matlab, Mathematica (mechanics, optics and quantum mechanics)/Atomistix and related softwares, Introduction to Labveiw software

Unit-III Introduction to Monte Carlo techniques, Random processes in science, Monte Carlo integration.

Unit-IV Applications and examples based on the Monte Carlo technique: Random walk, Percolation, Ising model, etc.

References: (NST 108)

1. 'Handbook of Theoretical and Computational Nanotechnology, Eds. Michael Rieth and Wolfram Schommers, 2006.
2. Introductory Computational Physics Kelvin and Godunov (Cambridge).
3. Computational Physics, R.C. Verma, K.C. Sharma & P.K. Ahluwalia.

Course Expected Outcomes:

CEO_1	The students are expected to develop the flavour of modelling and simulation.
CEO_2	To generate working knowledge of MATLAB/ MATHEMAICA.
CEO_3	To gain working knowledge of Linux operating system.
CEO_4	To solve some famous but basic physics problems using simulation.

Course Code : NST 110 **Title: Solutions & Surface Phenomena**

L/T/P: 4/0/0 **Credits– 04**

Course Objectives:

CO_1	This paper provides an understanding of surfactants, micellar chemistry, self-assembly, phase behavior of surfactant systems.
CO_2	It deals with physico-chemical properties of surfactants like wetting, foaming etc..
CO_3	Another crucial objective of this paper is to provide an overview of the concepts of colloids, colloidal forces including electrical double layer and an overview of adsorption.
CO_4	The paper provides knowledge about the process of phase transformation.

Course Contents:

Unit – I Adsorbtions on Solid Surfaces Freudlich and Langmuir Adsorption Isotherm. Gibbs Isotherm. Homogeneous and Heterogeneous Catalysis and its fundamental understanding at nanoscale. Role of nanometal and semiconductor particles in industry.

Unit – II Surface Chemistry: Colloidal state: Interfacial Porperties, Origin of Charge on Colloidal Particles, Determination of size of colloidal particles; Types of surfactants: Anionic, cationic, 30emini, zwitterionic& non-ionic (non-iogenic); Theory of surfactants; CMC – Effect of chemical structure, temperature; Kraft temperature; Emulsions & gels

Unit – III Phase Behaviour of Concentrated Surfactant Systems: Micelle type, Micellar growth, Micellar solution saturation; Structure of liquid; crystalline phases; Phase rule, Phase diagram, Binary and ternary phase diagrams of two components & three components, Surfactant geometry & packing; Introduction to microemulsion

Unit–IV Phase Transformations: Mechanisms of phase transformation; homogeneous and heterogeneous nucleation; spinodal decomposition; grain growth; precipitation in solid solution; transformation with constant composition; order-disorder transformations; Martensitic transformation

References: (NST 110)

1. Surfactants and Polymers in Aqueous Solution – K. Holmberg, B. Jonsson, B. Kronberg, B. Lindman, Wiley – England 2004.
2. Dynamics of Surfactant Self – Assemblies – Raoul Zana (Ed.), Taylor & Francis.
3. "Colloidal Dispersion" – Russel W. B, Saville D. A &Schowalter W. R, Cambridge University Press, 1989.
4. Fundamentals of Interface and Colloid Science – Lyklema J, Academic Press, Vol- 2
5. Introduction to Surface Physics – Martin Prutton, Oxford University Press (1994)
6. Introduction to Thermodynamics of Materials, - Gaskell, David R, 4th edition (1995), Taylor and Francis Publishing.

Approved in 27th Meeting of the Academic Council held on 15-06-2009. Agenda Item No. 27.9

Course Expected Outcomes:

CEO_1	The students will be able to appreciate the developments and advancements in the area of surfactants.
CEO_2	They will be able to relate the structure of the surfactant suited for a specific application.
CEO_3	They will be able to build strong concepts on colloidal chemistry and adsorption.
CEO_4	The students will have adequate knowledge about the important process of phase transformation.

Course Code: NST-112 **Title: Business Enterprise in Nanotechnology & Project management**

[NUES] **L/T/P: 1/0/0**

Course Objectives:

CO_1	This course aims at imparting knowledge in respect of organizational and managerial structure of Indian businesses.
CO_2	The students will learn team work, Communication and interpersonal skills.

COURSE DESCRIPTION/ OBJECTIVES:

This course aims at imparting knowledge in respect of organizational and managerial structure of Indian businesses. Besides acquiring skills related to decision making, the students will be introduced to the tools and techniques, like PERT/CPM etc., for effective project management. The students will gain knowledge and experience through lectures, case studies and special topic presentations.

Lecture Schedule:
Lecture 1. : Indian Business Enterprise
Lecture 2 : Business Organization design and structure
Lecture 3. : Introduction to Organization Behavior
Lecture 4: Team building and Motivation
Lecture 5: Leadership, Communication and interpersonal skills
Lecture 6 : Managing R&D and Innovations
Lecture 7: Entrepreneurship
Lecture 8 :Analyzing business environment
Lecture 9: Decision Making techniques
Lecture 10: Project Management
Lecture 11: PERT / CPM – I
Lecture 12 : PERT / CPM – II
Lecture 13 : Presentations

References: (NST: 112)

1. Concept Document "Nanoscience & Technology Initiative" of DST, GOI, New Delhi.

Course Expected Outcomes:

CEO_1	The students will acquire skills related to decision making and tools and techniques, like PERT/CPM etc., for effective project management.
CEO_2	The students will learn to manage R&D and Innovations and develop an orientation towards Entrepreneurship.

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Course Code: NST-152 **Title: Laboratory-II**
L/T/P: 0/0/12 **6 Credits**

Course Objectives:

CO_1	The objective of this course is to have some experiments based on the applications of surface/interface phenomena.
CO_2	**Group A:** The experiments designed are such that the students are able to apply the already learnt concepts towards developing processes leading to soft synthesis of nanomaterials in a more controlled way. **Group B:** The students will explore a close correlation between the physical properties and applications of nanomaterials.
CO_3	The students will study the impact of size on various physical and chemical properties of nanomaterials by real time hands on practical. The experiments designed are advanced and the students are exposed to RF/DC magnetron sputtering, thermal evaporation, AFM, Raman Spectroscopy and electrical measurements.
CO_4	They also learn detailed writing, data analysis and discussion of results. This lab course aims to blend the concepts learnt by the students in their theory & lab and takes them towards designing hybrid fabrication techniques for developing nanomaterial-based devices.

Course Contents:

Section A

1. To investigate adsorption of oxalicacid from aqueous solution by activated charcoal and examine the validity of Freundli chand Langmuir adsorption isotherm.
2. Determination of critical micelle concentration of ionic surfactant (Sodium Dodecyl Suphate) in water by conductivity method. (Determine cell constant using 0.01 MKCl solution).
3. Determination of mutual solubility curve of phenol & water, and hence the consulate point / critical solution temperature (CST). To study the effect of presence of salt to the above system.
4. Preparation of water-in-oil micro emulsion and measurement of droplet sizes by Dynamic Light Scattering (DLS).
5. Study the effect of salt & valency of adsorbing ionson particle dispersion stability.
6. Preparation of quantum dots (ZnS) nano particles using water-in-oil micro emulsion and to estimate the band gap by band gap edge method using UV-Vis spectroscopy.
7. To prepare cholesteric liquid crystals and study the relationship between transition temperature and composition.

Section B

1. Synthesize copper oxide nanoparticles by sol-gel method and determine the average size of nanoparticles using Zetasizer.
2. Synthesize nickel oxide nanoparticles by sol-gel method and determine the average size of nanoparticles.
3. Fabricate silver nanoparticles embedded in silica glass by ion exchange method and study surface plasmon resonance using UV-visible spectroscopy.

4. Fabricate copper nanoparticles embedded in silica glass by ion exchange method and determine the size of nanoparticles using optical absorption spectroscopy.
5. Synthesize silver nanocrystals in solution by citrate reduction method and study the effect of capping using optical absorption spectroscopy.
6. Study the growth kinetics of silver nanoparticles embedded in ion exchanged glass at different temperatures using optical absorption spectroscopy.

Course Expected Outcomes:

CEO_1	The students will learn the fundamental concepts of surface/interface phenomena.
CEO_2	Section A: The students will develop fairly good skills towards soft synthetic routes. Section B: Calculation and interpretation of some fundamental physical parameters such as bandgap, particle size determination, identification of hydrodynamic radius, fingerprinting with UV-Vis, Raman spectroscopy, XRD will be learnt by the students
CEO_3	They will be able to correlate various process parameters with the physical properties of nanomaterials. Basic introduction to electrical properties and their usage will arm them for minor & major projects in manipulating nanomaterials suited for a particular application.
CEO_4	Calculation and interpretation of some fundamental physical parameters such as bandgap, particle size determination, identification of hydrodynamic radius, fingerprinting with optical measurements and DLS will be learnt by the students. The students will be able to blend the concepts learnt in their theory & lab and move towards designing hybrid fabrication techniques for developing nanomaterial-based devices.

Course Code: NST-154 **Title:Self Study-II**

L/T/P: 0/3/0 **3Credits**

Course Objectives:

CO_1	This is a step forward from Self-Study I.
CO_2	Students are expected to prepare presentations after a more rigorous and diligent literature survey under the close guidance of the NST faculty.
CO_3	Students are expected to assimilate and keep presenting their updated continuous study to the faculties and peers throughout the semester.
CO_4	This will enable them to understand the topic thoroughly and help them prepare strong and quality presentations with adequate defense skills.

Course Contents:

Presentations will be made by the students on emerging topics assigned and supervised by the faculty. The presentations will be subjected to internal and external evaluations.

Course Expected Outcomes:

CEO_1	The presentation skill of the students will be sharpened to professional level.
CEO_2	The students will be able to assimilate the concepts through continuous study and discussions with the faculties throughout the semester.
CEO_3	The students will be able to understand the topic thoroughly and prepare strong and quality presentations with adequate defence skills.

Course Code : NST 156 **Title: Scientific Computation &Simulation**

L/T/P: 0/0/4 **2 Credits**

<u>Contents</u>

Both 108 and 156 are companion courses and go together as an introduction to programming with Matlab. The syllabus willremainsame as for the paper NST-108.The studentswillbe made to practice and learncomputationalwork in this lab.

*Note : Course Objectives and Course expected outcomes are same for both NST 108& NST 156

Course Code: NST-201 **Title: Advanced Nanomaterials**
L/T/P: 3/0/0 3 Credits

Course Objectives:

CO_1	To learn fundamentals of magnetism.
CO_2	To understand the effect of nanoscale on magnetism and its various applications.
CO_3	To enable students to learn about carbon nanostructures such as fullerenes and their various properties and usage.
CO_4	Learning about the thermoelectrics and its nanostructured version and their application and current status.

Course Contents:

Unit-I Fundamentals of magnetic materials, Dia, Para, Ferro, Antiferro, Ferri, Superpara magnetic materials AND giant and colossal magneto-resistance.Important properties in relation to nanomagnetic materials.

Unit-II Nanostructure Magnetism; Effect Bulk Nanostructuring of Magnetic property; Gaint and colossal Magnetic resistance; Super Para Magnetism in metallic nanoparticle; Super para magnetism / FM in Semi-conduction quantum dots.

Unit-III Carbon Nano Structures: Introduction; Fullerenes, C60, C80 and C240 Nanostructures; Properties & Applications (mechanical, optical and electrical).

Unit-IV Thermo Electric Materials (TEM): Concept of phonon, Thermal conductivity, Specific heat, Exothermic & endothermic processes. Different types of TEM; Bulk TEM Properties. One dimensional TEM; Composite TEM; Applications.

References: (NST-201)

1. Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor***;*** ISBN 9780367393649; Published September 16, 2019 by CRC Press
2. Physics of Magnetism - S. Chikazumi and S.H. Charap; ISBN:9780471155355, 0471155357;Published:15 January 1964; Publisher: Wiley
3. Physical Theory of Magnetic Domains - C. Kittel. Review of Modern Physics, Vol. 21, Number 4, October 1949
   Magnetostriction and Magnetomechanical Effects - E.W. Lee. *Rep. Prog. Phys.* **18** 184
4. Nanoscale materials -Liz Marzan and PV Kamat. (2003) Nanoscale materials. Springer, Berlin.
5. Physical properties of Carbon Nanotube- Riichiro Saito, Gene Dresslhaus, and M. S. Dresselhaus; Publisher: Imperial College Press (London) (July 22, 1998) , ISBN 1-86094-093-5
6. Applied Physics Of Carbon Nanotubes : Fundamentals Of Theory, Optics And Transport Devices
   - S. Subramony& S.V. Rotkins; Springer; 2005th edition (21 June 2005)

Approved in 27th Meeting of the Academic Council held on 15-06-2009. Agenda Item No. 27.9

7. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell; CRC Press; 1st edition (3 October 2018)
8. CARBON NANOTECHNOLOGY- Liming Dai; 1st Edition, Elsevier (2006)
9. Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing (2011), ISBN 978-1-84973-058-7.
10. CRC Handbook of Thermoelectrics, Ed. CR Rowe ; Published: (July 14, 1995) CRC Press

Course Expected Outcomes:

CEO_1	To understand the basic magnetism.
CEO_2	To learn about the various types nanomagnetic materials, their special properties such as superparamagnetism.
CEO_3	To various carbon nanostructures such as fullerenes, their synthetic and purification strategies, various chemical and physical properties, and applications in various fields .
CEO_4	To learn about thermoelectric and its nanostructured version and their application .

Course Code: NST-203 **Title: Semiconductor nanostructures and Nanoparticles**

L/T/P: 3/0/0 3 Credits

Course Objectives:

CO_1	This course focusses on giving students exposure to semiconductor nanostructures, their synthetic strategy using various state of the art physical and chemical methods.
CO_2	A brief study of their properties to develop understanding of various important concepts, such as phase transformation, metling point, quantum confinement.
CO_3	To study size dependent physical properties of semiconductor nanocrystsls. Unit -III provides information on effect of particle engineering on band gap and quantum yield of luminescence of semiconductor nano crystals/ nanostructures.
CO_4	Various aspects of quantum dots, other interesting structures, and their important properties such as quantum conductance are introduced.

Contents:

Unit –I Semiconductor nanoparticles Synthesis, Cluster compounds, quantum-dots from MBE and CVD, wet chemical methods, reverse micelles, electro-deposition, pyrolytic synthesis, self-assembly strategies.

Unit –II Semiconductor nanoparticles: size–dependant physical properties, Melting point, solid-state phase transformations, excitons, band-gap variations-quantum confinement, effect of strain on band-gap in epitaxial quantum dots, single particle conductance.

Unit-III Semiconductor nanoparticles – applications, Optical luminescence and fluorescence from direct band gap semiconductor nanoparticles, surface-trap passivation in core-shell nanoparticles, carrier injection, polymer-nanoparticle, LED and solar cells, electroluminescence, barriers to nanoparticle lasers, doping nanoparticles, Mn-Zn-Se phosphors, light emission from indirect semiconductors, light emission form Si nanodots.

Unit-IV Semiconductor nanowires, Fabrication strategies, quantum conductance effects in semiconductor nanowires, porous Silicon, nanobelts, nanoribbons, nanosprings.

References: (NST – 203)

1. Encyclopedia of Nanotechnology- Hari Singh Nalwa
2. Springer Handbook of Nanotechnology - Bharat Bhusan
3. Handbook of Semiconductor Nanostructures and Nanodevices Vol 1-5- A. A. Balandin, K. L. Wang.
4. Nanostructures and Nanomaterials - Synthesis, Properties and Applications - Cao, Guozhong.

Course Expected Outcomes:

CEO_1	The students will develop ideas about semiconductor nanostructures, various aspects of synthetic strategies.
CEO_2	They will understand various important properties in nanoscience and technology associated with such structures and their applications, some of which are part of Lab classes as well.
CEO_3	Important aspects of current state of the art semiconductor nanostructures, their possible applications,limitation and challenges will be clear to them.
CEO_4	Various current applications such as phosphors, porous silicon, and their light emitting properties will be in their repertories for future applications in the field of nanoelectronics and nanobio science.

Electives

Course Code: NST 205 **Title: Molecular Nanoelectronics** **L/T/P:3/0/0**

Course Objectives:

CO_1	To understand various theoretical aspects of nanoelectronics.
CO_2	To gain an insight into the components of molecular electronics and various applications.
CO_3	To develop a knowledge base for nanoelectronicandnanocomputers and molecularcircuitsNanocomputerArchitectures.
CO_4	To grasp the various aspects of spintronics, theory behind spinInjection,spinrelaxationandspindephasingand spintronicdevices.

Unit–I Introduction: Recent past, the present and its challenges, Future, Overview of basic Nano electronics.

Unit–II Molecular Electronics Components: Characterization of switches and complex molecular devices, polyphenylene based Molecular rectifying diode switches. Technologies, Single Electron Devices, Quantum Mechanical Tunnel Devices, Quantum Dots & Quantum wires.

Unit–III Nanoelectronic & Nano computer architectures and nanotechnology: Introduction to nanoelectronic and nanocomputers, Quantum DOT cellular Automata (QCA), Single electron circuits, molecular circuits Nanocomputer Architecture.

Unit–IV Spintronics:

Introduction, Overview, History & Background, Generation of Spin Polarization Theories of spin Injection, spin relaxation and spin dephasing, Spin tronic devices and applications, spin filters, spin diodes, spin transistors.

References: (NST205)

1. Nanoelectronics & Nanosystems: From Transistor to Molecular & Quantum Dvices: Karl Goser, Jan Dienstuhl and others.
2. Concepts in Spintronics–Sadamichi Maekawa
3. Spin Electronics– David Awschalom
4. From Atom to Transistor-Supriyo Datta

Course Expected Outcomes:

CEO_1	The students will understand various theoretical aspects of nanoelectronics.
CEO_2	The students will develop a comprehensive insight into the components of molecular electronics and various applications.
CEO_3	The students will assimilate a knowledge base for nanoelectronic and nanocomputers and molecular circuits Nanocomputer Architectures.
CEO_4	The students will understand the various aspects of spintronics, theory behind spin Injection, spin relaxation and spin dephasing and spintronic devices.

Course Code: NST 207 **Title: Photonics and Plasmonics**

L/T/P:3/0/0

<u>Course Objectives</u>:

CO_1	To understand various theoretical aspects of photonics.
CO_2	To gain an insight into various aspects of photonic crystals, problems and emerging solutions, and various applications.
CO_3	To develop a knowledge base for near field optics, the devices involved, and various applications.
CO_4	To grasp the various aspects of the theory, materials, fabrication, and application of plasmonics.

Physics of Linear Photonic Crystals: Maxwell's Equations, Bloch's Theorem, Photonic Band Gapand Localized Defect States, Transmission Spectra, Nonlinear Opticsin Linear Photonic Crystals, Guided Modesin Photonic Crystals Slab

Technology, Materials, and Fabrication of Photonic Crystals: Choices of Materials: Semiconductors, Amorphous, and Polymers, Fabrications of Photonic Crystals Structures (1-D, 2-D, 3-D)

Applications of Photonic Crystals Devices: 1-D Photonic Crystals, Couplers, Wave guides, High-Q Cavities, etc, 2-D Photonic Crystals, Photonic Crystal Fibers, 4 Tunable Photonic Crystal Filters

Physics of Non linear Photonic Crystals: 1-D Quasi Phase Matching, Non linear Photonic Crystal Analysis, Applications of Non linear Photonic Crystals Devices, Materials: $LiNbO_3$, Chalcogenide Glasses, etc, Wave length Converters, etc

Elements of Plasmonics: Introduction to Plasmonics, merging photonics and electronics at nanoscaledimensions, single photon transist or using surface plasmon, nano wire surface plasmons-interaction with matter, single emitter as saturable mirror, photon correlation, and integrated systems. All optical modulation by plasmonic excitation of quantum dots, Channel plasmon-polariton guiding by sub wave length metal grooves, Near-field photonics: surface Plasmon polaritons and localized surface plasmons, Slow guided surface Plasmon sattelecom frequencies.

References:(NST207)

1. The Hand book of Photonics By Mool Chand Gupta, John Ballato
2. Nano technology for Micro electronics and Optoelectronics - J. M. Martinez-Duart, Raúl J. Martín - Palma, Fernando Agullo-Rueda
3. Nano plasmonics, From fundamentals to Applications vol 1 & 2 - S. Kawata & H. Masuhara

4. Optical Properties of Photonic Crystals - K. Sakoda
5. Applied Photonics by Chai Yeh
6. Silicon Photonics: An Introduction by Graham T. Reed, Andrew P. Knights

Course Expected Outcomes:

CEO_1	The students will understand various theoretical aspects ofphotonics.
CEO_2	The students will develop a comprehensive insight into various aspects of photonic crystals, problems and emerging solutions, and various applications.
CEO_3	The students will assimilate a knowledge base for linear and nonlinear near field optics, the devices involved, and various applications.
CEO_4	The students will understand the various aspects of the theory, materials, fabrication, and application of plasmonics.

Course Code: NST 209 **Title: Carbon Nanotubes & Its Functionalisation**

L/T/P: 3/0/0

Course Objectives:

CO_1	To provide students understanding of the structure, synthesis and applications of carbon nanotubes.
CO_2	To enable the students to understand the electronic, mechanical, vibrational and optical properties of carbon nanotubes.
CO_3	This will enable the students understand the different applications of carbon nanostructures.
CO_4	To provide students understanding of functionalization of carbon nanotubes required for different applications.

Preparation of Carbon Nano-Tubes: CVD and other methods of preparation of CNT

Properties of Carbon Nanotubes: Electrical, Optical, Mechanical, Vibrational properties etc.

Applications of Carbon Nanotubes: Field emission, Fuel Cells, Display devices

Functionalization of Carbon Nanotubes: Carbon Nanotubes, Functionalization of Carbon Nanotubes, Reactivity of Carbon Nanotubes,

Covalent Functionalization: Oxidative Purification, Defect Functionalization –Transformation and Modification of Carboxylic Functionalization like Amidation, Thiolation, Halogenations, Hydrogenation, Addition of Radicals, Addition of Nucleophilic Carbenes, Sidewall Functionlaization through Electrophilic Addition, Cycloadditions, Carbenes Addition, Addition of Nitrenes, Noncovalent Exohedral Functionalization, Endohedral Functionalization

Other Important Carbon based materials: Preparation and Characterization Fullerene and other associated carbon clusters/molecules, Graphene-preparation, characterization and properties, DLC and nanodiamonds.

References: (NST 209)

1. Nanoscale materials -Liz Marzan and Kamat
2. Physical properties of Carbon Nanotube-R Satio
3. Applied Physics Of Carbon Nanotubes : Fundamentals Of Theory, Optics And Transport Devices - S. Subramony& S.V. Rotkins
4. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell
5. CARBON NANOTECHNOLOGY- Liming Dai
6. Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing

Course Expected Outcomes:

CEO_1	The students will be able to understand the structure and different fabrication techniques used for preparing carbon nanotubes.
CEO_2	The students will be able to understand the different properties of carbon nanotubes.
CEO_3	The students will develop understanding for selecting carbon nanostructures suitable for different applications.
CEO_4	The students will be able to understand the aspects of functionalization of carbon nanotubes necessary for different applications.

CourseCode:NST211

Title:ComputationalNanoscienceL/T/P:3/0/0

Course Objectives:

CO_1	To provide students understanding of Matlab and Mathematica (and their open source counterparts-Scilab and Octave)
CO_2	To enable the students to understand the Monte Carlo Simulations; Computational methods and simulations from abinitio to multi scale Modeling.
CO_3	To reveal students to solve select problems on Molecular Dynamics
CO_4	To train students to simulate nano materials and nano devices using Mutliscale modeling

Unit –I Introduction to Matlab and Mathematics (and their open source counterparts-Scilab and Octave); examples from nano-optic sand nano-electronics.

Unit–II Monte Carlo Simulations; Computational methods and Simulations from abinitio to multi scale Modeling.

Unit–III Molecular dynamics, computing and simulations.

Unit–IV Nano design, Nano CAD, Modeling of Nano dvices. Applications and examples problems based on Molecular dynamics simulations.

References: (NST: 211)

1. Introduction to Computer simulation methods. Gould, Tobochniketal (Addition weekly - 2006)

Course Expected Outcomes:

CEO_1	The students will be able to understand Matlab and Mathematica (and their open source counterparts-Scilab and Octave)
CEO_2	The students will be able to understand the Monte Carlo Simulations; Computational methods and Simulations from abinitio to multi scale Modeling.
CEO_3	The students will be ableto solve select problems on Molecular Dynamics
CEO_4	The students will be ableto simulate nano materials and nano devices using Mutli scale modeling

Course Code : NST - 213 **Title: IPR & Nanotechnology**
L/T/P : 1:0:0 (NUES)

<u>Course Objectives</u>:

CO_1	This paper enables the students to learn the basics of IPR.
CO_2	Provides an understanding of IPR issues related to Nanoscience & Nanotechnology.

Contents:

Nano technology with its vast potential applications in day to day life will surely face lot of legal challenges. The objective of this course will be focused towards sensitizing the students towards relating IPR with relation to Nano Science

Course Expected Outcomes

CEO_1	The students will get an understanding of IPR related issues to be considered by them during their research and R&D
CEO_2	The students will know the procedure and requirements to apply for patents.

Course Code : NST 215 **Title: Nanocomposites**

L/T/P : 3/0/0 **Credits– 03**

Course Objectives:

CO_1	To enable students to learn the basic preparation of various types of nanocomposites.
CO_2	To enable students to learn the properties and applications of different nanocomposites.
CO_3	To enable students to understand the design of new kind of nanocomposites.
CO_4	The students will learn about polymer based nanocomposites, their mechanical properties and applications.

Course Contents:

Unit I: Types of Nanocomposites: (11 hours)
Introduction to polymers, ceramics and nanocomposites, Classification based on matrix materials: Ceramic matrix nanocomposites, Metal matrix nanocomposites, Polymer matrix nanocomposites, Different aspects of their preparation techniques.

Unit II: Properties, functionality and Applications of Nanocomposites: (12 hours)
Properties, functionality and applications of ceramic matrix nanocomposites, metal matrix nanocomposites, polymer matrix nanocomposites.

Unit III: Novel Nanocomposites: (11 hours)
Super hard nanocomposites, their designing for improved mechanical properties, Core-Shell structured nanocomposites and their surface-trap passivation, Hybrid nanostructures.

Unit IV: Polymer based nanocomposites: (10 hours)
Preparation and characterization of diblock copolymer based nanocomposites, Polymer-carbon nanostructures based nanocomposites, their mechanical properties and industrial possibilities.

References: (NST-215)

1. Nanocomposite Science and Technology - P. M. Ajayan, L. S. Schadler, P. V. Braun, Wiley, New York, ISBN: 9783527303595, 9783527602124, 2003.
2. Encyclopedia of Nanoscience and Nanotechnology - Hari Singh Nalwa, American Scientific Publishers, 2004.
3. The search for novel, superhard materials (Review Article), Stan Veprek, J. Vac. Sci. Technol. A 17(5), 2401-2420, 1999.
4. Multifunctional composite core-shell nanoparticles, Suying Wei, Qiang Wang, Jiahua Zhu, Luyi Sun, Hongfei Lin, Zhanhu Guo, Nanoscale, 3, 4474-4502, 2011.
5. Nanocomposites: Synthesis, Structure, Properties and New Application Opportunities, Pedro Henrique Cury Camargo, Kestur Gundappa Satyanarayana, Fernando Wypych, Materials Research, 12, 1-39, 2009.
6. Block Copolymer Nanocomposites: Perspectives for Tailored Functional Materials (Review Article), M. R. Bockstaller, R. A. Mickiewicz, E. L. Thomas, Adv. Mater., 17, 1331-1349, 2005.

Approved in 27th Meeting of the Academic Council held on 15-06-2009. Agenda Item No. 27.9

<u>Course Expected Outcomes</u>:

CEO_1	The students will study different aspects of the preparation techniques, properties and functionality of Metal, Ceramic and Polymer matrix nanocomposites
CEO_2	The students will be able to understand the properties, functionality and applications of ceramic matrix nanocomposites, metal matrix nanocomposites, polymer matrix nanocomposites.
CEO_3	The students will be able to understand the design of Super hard nanocomposites, Core-Shell structured nanocomposites and Hybrid nanostructures.
CEO_4	The students will be able to grasp the details of polymer based nanocomposites, their mechanical properties and applications.

Course Code : NST 251 Title : Self-Study-III

L/T/P : 0/2/0 Credits : 02

Course Objectives:

CO_1	This is a step forward from Self-Study I& Self-Study II.
CO_2	Students are expected to prepare presentations after a more rigorous and diligent literature survey under the close guidance of the NST faculty.
CO_3	Students are expected to assimilate and keep presenting their updated continuous study to the faculties and peers throughout the semester.
CO_4	This will enable them to understand the topic thoroughly and help them prepare strong and quality presentations with adequate defense skills.

Course Contents:

Presentations will be made by the students on emerging topics assigned and supervised by the faculty. The presentations will be subjected to internal and external evaluations. This is aimed at the individual student's field of interest/relevance based on their evolution.

Course Expected Outcomes:

CEO_1	The presentation skill of the students will be sharpened to professional level.
CEO_2	The students will be able to assimilate the concepts through continuous study and discussions with the faculties throughout the semester.
CEO_3	The students will be ableto understand the topic thoroughly and prepare strong and quality presentations with adequate defence skills.
CEO_4	The students from different backgrounds will evolve as proper Nanoscience and Technology students and develop taste and inclination towards specific lines of research/industrial applications.

Course Code : NST 253 **Title : Minor Project**

Credits : 05

Course Objectives:

CO_1	Having trained in basics of synthesis and characterization through laboratories I & II and being prepared by self-studies and theoretical course work, the students are ripened enough to start thinking about how to design their own projects in consultation of the faculty.
CO_2	These minor projects are prelude to final semester major project and can be either experimental or theoretical in nature or even a combination of the two. However their nature is basic and objective limited and short.
CO_3	The minor project is carried out in-house. But, in order to expose the student to some rare techniques the faculty may think about collaborative approach with other institutes in the country.
CO_4	This will enable the students to beconversant with various equipment with hands on training while carrying out the project. The students are expected to carry out proper literature survey and learn report writing.

Course Contents:

In Minor project the students become increasingly focused towards their research interests, take one particular problem and carry out experimental/theoretical study during this duration. At the end of the semester the students will submit project report and are evaluated on the basis of their presentation, understanding of the subject and analysis of the results. The project will be examined for internal evaluation followed by an external examination involving a presentation and submission of project report.

Course Expected Outcomes:

CEO_1	The students will learn to think about a complete but short project and its design and execution aspect.
CEO_2	They will become conversant with various instruments with hands on approach. They will learn proper literature survey and report writing.
CEO_3	They will learn to work in a goal-oriented way and will develop skills for collaborative research.
CEO_4	They will learn to plan and execute the project in a time-bound manner and present their results in a professional way. The students from different backgrounds will evolve as proper Nanoscience and Technology students and develop taste and inclination towards specific lines of research/industrial applications.

Course Code : NST 255 **Title : Summer Training (Viva-voce)**
Credits : 04

Course Objectives:

CO_1	The overall objective of the Summer Training is to train the students to the real research world by working either in house or in other research institutes / industries / universities.
CO_2	The students should have exposure and hands-on-experience.
CO_3	The students should find themselves in a position to channelize their research interests and be able to develop a clarity on the future objectives that they would like to achieve in the following semesters of the course.
CO_4	This will enable the students to get a close insight into the best practices being followed at premium institutions.

Course Contents:

The students will proceed for Summer Training at the end of second semester for a period of 6-8 weeks. The students will then submit the training report after its completion and make a presentation which will be subjected to internal and external evaluations.

Course Expected Outcomes:

CEO_1	The students should find themselves in a position to channelize their research interests and be able to develop a clarity on the future objectives that they would like to achieve in the following semesters of the course.
CEO_2	The students doing their summer training outside the GGSIPU will get introduced to new mentors, scientists and potential collaborators.
CEO_3	The students will learn disciplined work culture of sophisticated research labs & team spirit.
CEO_4	The students will gain valuable exposure and hands-on-experience.

Course Code : NST 202 **Title: Project Work/ Internship (Seminar)**

Credits– 20

Course Objectives:

CO_1	The major project is the key attribute of the entire course. The students, in conjunction with the faculty, will design and execute a relevant project, where they are supposed use all the skills they have acquired through theoretical course work, laboratories I&II,self-study I, II&III, summer training and the minor project.
CO_2	The work must represent original thinking process, proper literature survey, relevance to current field of emergence. Preferably, the project can be related to the existing or future research area of the faculty.
CO_3	The students will be continuously evaluated throughout the period through presentations and interactions with the faculties.
CO_4	In-house projects are preferred, but in exceptional cases the coordinator may allow partial or complete execution of the project in other institutes of repute with justification.

Course Contents:

Major Project will be undertaken by students in either experimental or theoretical work. It could be carried out either in house, i.e., involving the University Schools and facilities or in industry / research organizations for a period of 6 months alongwith the preparation of a dissertation. In both cases an internal supervisor from the USBAS is mandatory and an external collaborating supervisor can be involved if needed. The project will be examined for internal evaluation followed by an external examination involving a presentation and final submission of dissertation. Original work leading to a publication will been couraged.

Course Expected Outcomes:

CEO_1	The student will learn to design and execute a research work in a time bound manner. Following this process, they will become “Research and Industry Ready”.
CEO_2	They will develop special interest with meaningful body of work in the field of Nano Science and Technology, based on their training and background.
CEO_3	They should be able to produce a publishable/patentable work.
CEO_4	They will be encouraged to present their work in National and International conferences.

Course Code : NST 204 **Title: Comprehensive Viva Voce**

Credits : 05 NUES

Course Objectives:

CO_1	The Comprehensive viva voce is to test whether the students have finally assimilated all the aspects studied.
CO_2	It tests the knowledge gained during the various theoretical and experimental training.
CO_3	More emphasis is laid upon testing the understanding acquired by the students during their summer training, minor &major projects.
CO_4	The students should be able to intertwine several concepts learnt across disciplines during the entire course.

Course Contents:

Comprehensive Viva Voce is an internal and external evaluation via a viva voce covering all aspects of the programme including the major project.

Course Expected Outcomes:

CEO_1	The students will be able to put together various concepts and integrate the knowledge base developed in this programme.
CEO_2	The students will finally understand where they stand in the entire scenario of nanoworld research.
CEO_3	They will be able to analyze their relative strengths and weaknesses.
CEO_4	The students should be able to display high level of conviction as they face the viva with the external examiner.