AC- 07/07/2023
Item No. -6.26 (N)

As per NEP 2020

UNIVERSITY OF MUMBAI

Title of the program

A.	P.G. Diploma in Nanosciences and Nanotechnology	}	2023-24
B.	M.Sc. (Nanosciences and Nanotechnology) (Two Year)		
C.	M.Sc. (Nanosciences and Nanotechnology) (One Year)		2027-28

Syllabus for M.Sc. (Nanosciences and Nanotechnology)

Semester- I and II

Ref. GR dated 16th May, 2023 for Credit structure of PG

PREAMBLE

1. Introduction:

Considerable research over the past decade has shown that nanoscience played a vital role in developing new generation technologies commonly known as nanotechnology has crossed almost all boundaries of sciences. Hence to initiate cognizance of ongoing research activities in the said field, center has introduced two years post-graduation course work entitled "Masters of Science in *Nanosciences and Nanotechnology*". The course work designed herewith not only provide the fundamental understanding of the subject to students but also offers them flexibility to work as an interdisciplinary approach to seek for possible solutions by developing in house technologies to address the problems society facing now a days. Looking at the ongoing demand of fourth generation industrial revolution, the course work designed herewith not only literate but also motivate young generation in this field to reduce the gap via scientific/research activities followed by in house technological breakthroughs. Care taken especially to train and develop the required skillsets in the students while designing the course work will definitely help students to prepare them for the next generation industrial opportunities.

2. Aims and Objectives:

- To provide exposure to students in various specializations of Nanosciences and Nanotechnology.
- To undertake the capacity building of human resource in the field of recent developments in Nanoscience and nanotechnologies.
- Collaborate with national and international researcher institutes and industries for the development of high-end new generation of technologies.
- Motivate young minds for taking up Nano Science R&D as career and their skill developments,
- Motivate students towards the conducive environment for creation and commercialization of in house technologies.

3. Learning Outcomes:

Students who complete the course will understand the following,

- The fundamental knowledge of various subjects essential to understand nanosciences.

- The knowledge of various nanomaterials, their properties, synthesis routes and characterization techniques.
- Provide exposure in various specialization of Nanotechnology.
- Develop skills on modern developments in materials at the nanoscale and their relationship with the classical concepts.
- Develop skills on modern and state of art equipment's to be used to characterize nanomaterials, pattern them via top down and bottom up approaches to design new nanotechnology based systems (especially MEMS and NEMS).
- Practical understanding of descriptive data analysis, sampling theory, testing of hypotheses, nonparametric methods and multivariate analysis.
- Develop skills to address various societal issues via developing in house technologies.
- Building of human resource development in Nano Science and nanotechnology.
- Motivate young minds for taking up Nano Science R&D as career.
- Motivate students towards the conducive environment for creation and commercialization of in house technologies.

4. **Any other point (if any):**
   - During course work students will be provided hand on training on highly sophisticated state of art microscopy and spectroscopy equipment's.
   - Students will be provided internship at various industries looking at their choice of preference.
   - Via assigning short term and research projects students will be motivated to design and commercialization their in house technologies.
   - Collaborate with national and international researchers/industries for the development of high-end new generation of technologies based on nanosciences.

5. Credit Structure of the Program (Sem I, II, III & IV)
(Table as per Parishisht 1 with sign of HOD and Dean)

Post Graduate Programs in University — Parishishta - 1

Year (2 Yr PG)	Level	Sem. (2 Yr)	Major		RM	OJT / FP	RP	Cum. Cr.	Degree
			Mandatory*	Electives Any one					
I	6.0	Sem I	CNN 501: Physics of Materials (Cr. 4) CNN 502: Chemistry of Materials (Cr. 4) CNN 503: Bio-nano Materials Cr. 4) CNN 504: Practical Course I (Cr. 2)	CNN 505-A OR CNN 505-B (Cr. 4)	CNN 506 (Cr. 4)			22	PG Diploma (after 3 Year Degree)
		Sem II	CNN 511: Fundamentals of Nanomaterials (Cr. 4) CNN 512: Experimental Methods (Cr. 4) CNN 513: Micro-nano fabrication techniques (Cr. 4) CNN 514: Practical Course II (Cr. 2)	CNN 515-A OR CNN 515-B OR CNN 515-C OR CNN 15-D (Cr. 4)		CNN 516 Industrial visits (Cr. 4)		22	
Cum. Cr. For PG Diploma			28	8	4	4	-	44	

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Exit option: PG Diploma (44 Credits) after Three Year UG Degree									
II	6.5	Sem III	CNN 601: Advanced Instrumentation techniques (Cr. 4) CNN 602: Physics of semiconductors -I (Cr. 4) CNN 603: Fundamentals of spectroscopy (Cr-4) CNN 604: Practical III (Cr. 2)	CNN 605-A OR CNN 605-B OR CNN 605-C OR CNN 605-D (Cr. 4)			CNN 606 Short term project (Cr. 4)	22	PG Degree After 3- Yr UG
		Sem IV	CNN 611: Quantum electronic devices (Cr. 4) CNN 612: MEMS/NEMS and Microsystems (Cr. 4) CNN 613: Practical IV (Cr. 2)	CNN 614-A OR CNN 614-B OR CNN 614-C OR CNN 614-D (Cr. 4)			CNN 616 Research Project (Cr. 8)	22	
Cum. Cr. for 1 Yr PG Degree			**26**	**8**			**10**	**44**	
Cum. Cr. for 2 Yr PG Degree			**54**	**16**	**4**	**4**	**10**	**88**	

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Electives Suggested

SEM I		SEM II		SEM III		SEM IV	
Course Code	**Course Name**	**Course Code**	**Course Name**	**Course Code**	**Course Name**	**Course Code**	**Course Name**
CNN-505-A	Essential Mathematics	CNN-515-A	Nanomaterial synthesis techniques (PVD and CVD)	CNN-605-A	Nanotechnology in space and defense	CNN-614-A	Nano-Photonics and Biophotonics
CNN-505-B	Numerical recipes methods for data analysis using python	CNN-515-B	Electronics and circuit designing	CNN-605-B	Nanotechnology in energy and power storage devices	CNN-614-B	Nanomagnetic Materials and Devices
		CNN-515-C	Computing nanomaterials	CNN-605-C	Nanotechnology in medical, food and agriculture sector	CNN-614-C	Microwave and millimeter wave circuit design
		CNN-515-D	Thermodynamics and catalysis of nanomaterials	CNN-605-D	Interfacing and machine learning-I	CNN-614-D	Interfacing and machine learning-II

Note: * The number of courses can vary for totaling 14 Credits for Major Mandatory Courses in a semester as illustrated.

Sign of HOD
Name of the Head of the Department
Name of the Department

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Sign of Dean,
Name of the Dean
Name of the Faculty

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Program Educational Objectives (PSOs)
The two-year master's course in "Nanoscience and Nanotechnology" is designed with the focus to understand/develop various technologies in sectors for e.g. optoelectronics, electronics, space, energy sectors, agriculture, medicinal, biotechnology, etc. Considering the research over the past few decades that has shown that nanomaterials has played vital role in these sectors using various nano architectures/framework. The course proposed herewith provides a fundamental understanding towards the physical and chemical properties of these materials, methods to synthesize, characterize them. The micro and nanofabrication followed by hands on training provided to students on state of art instruments will provide enough confidence in the students to design/develop their own in house technologies.

Course Learning Outcomes (CLOs)

After the successful completion of each course the students are expected to	
SEMESTER I	
Mandatory Courses	
CNN 501	Comprehensive exposure to students regarding various materials viz. crystalline, non-crystalline their crystal structure and defects. Fundamental understanding towards them with respect to physical and chemical properties.
CNN 502	Comprehensive exposure to students regarding chemistry behind the materials such as metals, polymers and ceramics followed fundamental understanding of chemistry and properties behind nanomaterials, nanocomposites, etc.
CNN 503	Comprehensive exposure to students regarding biology/biological system followed by basics of bio-nano science/technologies for futuristic applications.
CNN 504	Confidence for self-learning, education and provide hands on experience towards material science, physics, chemistry and nano-bio systems and technologies based on these subjects.
CNN 506	Develop focuses on the methods and strategies and the way of conveying information in way to activate the intellectual property rights.
Elective Courses (Any one)	
CNN 505-A	Improved mathematical skill sets for describing materials and understand deep theory behind.
CNN 505-B	Improved inter-disciplinary concepts followed by possible computational simulation to interpret the natural phenomenon.
SEMESTER II	
Mandatory Courses	
CNN 511	Knowledge of advanced experimental/ theoretical methods used for measuring, observing and understanding various phenomenon that occurs at nanoscale and in various nano systems.
CNN 512	Skills development to know and design various physical and chemical synthesis techniques to grow nanomaterials in the laboratory as well as industries
CNN 513	Knowledge towards various lithography techniques followed by micro/nano fabrication processes.
CNN 514	Understanding how various electronic/semiconductor devices actually work followed by ability developed to analyze various electric circuits, design them to develop in house gadgets.
CNN 516	Comprehensive exposure to the industrial requirements and their functioning.
Elective Courses (Any one)	
CNN 515-A	Knowledge of nano material synthesis techniques and routes.
CNN 515-B	Skills developed to analyze and design electrical circuits one of the key requirements to develop in house gadgets/nano technology based products.
CNN 515-C	Aptitude to perceive, measure, operate and build materials at the nanometer scale, the size of atoms and molecules using various computational software available.
CNN 515-D	Knowledge about the catalytic performances, synthesis and characterization of various nano catalysts used in diverse sectors.

Syllabus for SEM I & II

Semester-I			
Mandatory Courses			
Sr. No.	**Course Name and Code**	**Proposed syllabus**	**Credits**
1	Physics of Materials (CNN 501)	**Objective(s) of the course:** 1. To give comprehensive exposure to the students regarding various materials; crystalline, non- crystalline materials, crystal structure and their defects. 2. To provide basic understanding to identify materials and their physical as well as chemical properties. **Crystal structure and interatomic forces**: (15 Lectures) Metals/ceramics/composites, intrinsic and extrinsic, Structure sensitive and Structure insensitive properties. Structure-property-processing co-relationship as a theme of materials science. Periodic Array of Atoms, Lattice Translation Vectors, Basis and the crystal structure, Primitive lattice cell, Fundamental Types of Lattices, Index System for Crystal Planes, Simple Crystal Structures, Imaging of Atomic Structure, Non-ideal Crystal Structures, Crystal Structure, Bragg Law, Fourier Analysis, Reciprocal lattice vectors, Diffraction Conditions, Laue Equations, Brillouin Zones, Structure factor of BCC and FCC Lattice, Atomic Form factor. **Elements of quantum mechanics:** (15 lectures) Photoelectric Effect, Compton Effect, Dual Nature of Electromagnetic Radiation, Photons, Matter Waves, Wave-Particle Duality, Uncertainty Principle, Properties of Matter Waves; Thomson's Model, Rutherford's Model, Atomic Spectra, Regions of atomic spectra, Bohr's Postulates, Bohr's & Sommerfeld's Model, Correspondence Principle, Born's Interpretation of Wave Functions, Expectation Values, Eigenfunctions and their properties, Energy Quantization, Time-independent Schrödinger equations; One-electron atoms (Development of the Schrödinger Equation, Solution of the Equations, Eigenvalues, Quantum Numbers, and Degeneracy, Eigenfunctions, Probability Densities, Orbital Angular Momentum, Eigenvalue Equations); Magnetic dipole moments, Spin, and Transition rates (Orbital Magnetic Dipole Moments, Electron Spin, Spin-Orbit Interaction, Total Angular Momentum, Spin-Orbit Interaction Energy, Hydrogen Energy Levels, Transition Rates and Selection Rules); **Structure of solids, conductors and semiconductors :**(15 Lectures) Crystals of Inert Gases: Van der Waals- London Interaction, Repulsive interaction, Equilibrium lattice constants, Cohesive energy, Madelung Energy and Madelung constant, Covalent Crystals, Metals, Hydrogen Bonds, Atomic Radii, Analysis of Elastic Strains, Elastic Compliance and Stiffness Constants, Elastic Waves in Cubic Crystals, Vibrations of	4

		Crystals with Monatomic Basis, First Brillouin Zone, Group velocity, Two Atoms per Primitive Basis, Quantization of Elastic Waves, Phonon Momentum, Inelastic Scattering by Phonons, Phonon Heat Capacity, Anharmonic Crystal Interactions, Thermal Conductivity, Band Gap, Electrical Conduction in Metals. **Magnetic and Dielectric Properties of Materials:** [15 Lectures] Different Type of Magnetic materials, Basic elements of magnetism, Magnetic moment due to electron and nuclear spin, Bohr Magneton, Diamagnetism, Classical Theory of Diamagnetism (Langevin's Theory), Langevin's Theory of Paramagnetism, Weiss Theory of Paramagnetism, Quantum theory of paramagnetism, Susceptibility determination, Ferromagnetism, Qualitative Explanation of Heisenberg's Internal Field and Quantum Theory of Ferromagnetism, Weiss molecular field, Temperature dependent behavior of ferromagnetic material, Ferromagnetic domains, explanation of Hysteresis, Antiferromagnetism, Ferrimagnetism. Fundamental Definitions in Dielectrics, Different types of Electric polarization, Frequency and Temperature Effects on Polarization, Dielectric Loss, Local Field on Internal Field Clausius-Mosotti Relation, Determination of Dielectric Constant Dielectric Breakdown, Properties of Different Types of Insulating Materials, Introduction to superconductivity. **Reference Books:** • Introduction to Solid State Physics by Charles Kittle; Wiley-India. ISBN 0-471-41526-X • Solid State Physics by Neil W. Ashcroft, N. David Mermin; Brooks/Cole Cengage Learning. ISBN, 8131500527 • Elementary Solid State Physics by M.A.Omar, Pearson Education. ISBN-10. 8177583778 • Solid State Physics by Allen J.Dekker, MacMillan India Ltd. ISBN, 354043870X • Introduction to quantum mechanics by D. Griffiths, Prentice Hall ISBN-10. 1108791107 • Quantum Mechanics by L. I. Schiff, McGrew Hill ISBN-13. 978-0070856431 • Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles by R. Eisberg, John Wiley and Sons ISBN-10. 047187373X	
2	Chemistry of Materials (CNN 501)	**Objective(s) of the course:** 1. To give comprehensive exposure to the students regarding chemistry behind materials that society depends on metals, polymers, and ceramics; 2. To provide basic understanding of chemistry/properties behind nanomaterials, nanocomposites, etc.	4

		Foundational chemistry: (15 lectures) The periodic table, elements and compounds, chemical formulas. Electron orbitals: Aufbau principle, Pauli exclusion principle, and Hund's rules, Primary bonding: ionic, covalent, metallic. Secondary bonding: dipole-dipole, induced dipole-induced dipole, London dispersion/van der Waals, hydrogen. Shapes of molecules: hybridization, LCAO-MO, VSEPR theory. Inorganic glasses: silicates, other oxides, metallic, Liquids and solutions: solubility rules, acids, bases, pH, Organic compounds: nomenclature, alkanes, alkenes, alkynes, aromatics, functional groups. Polymers: structure, composition, Phase stability: unary and binary phase diagrams **Chemical Kinetics:** (15 lectures) Accounting for the rate laws: simple reactions, temperature dependence of reaction rates, consecutive reactions, (rate determining step approximation and steady-state approximation), pre-equilibria, unimolecular reactions – Lindemann-Hinshelwood mechanism. Kinetics of complex reactions - Chain reactions, polymerization reactions, explosions, photochemical reactions. Fast reactions: Study of kinetics by stop-flow technique, relaxation methods, flash photolysis, magnetic resonance method. Molecular reaction dynamics – collision theory, steric factor, diffusion controlled reactions, activated complex theory, reaction coordinate and transition state, thermodynamic aspects, reaction between ions, salt effects, dynamics of molecular collisions, potential energy surfaces. Homogeneous catalysis – enzyme catalysis, Michael-Menten mechanism, acid base catalysis, autocatalysis, oscillating reactions. Heterogeneous catalysis – catalytic activity at surfaces. Examples: hydrogenation, oxidation, cracking and forming. **Chemical Bonding and Organometallic Chemistry:** (15 Lectures) Hybridisation: Derivation of wave functions for the following orbital hybridisation types: sp (BeH_2); sp2 (BF_3); sp3 (CH_4) considering only sigma bonding. Molecular Orbital Theory (LCAO-MO approach) for (a) Electron deficient species (B2H6), and (b) Electron rich species (tri-iodide ion, I3-). Hydrogen bonding–concept, types, properties, methods of detection and importance. Van der Waal's forces, ion-dipole, dipole-dipole, London forces. Bent's Rule. Reactivity of molecules: e.g. chlorofluorides of phosphorous, fluoromethanes, etc. Synthesis, structure and bonding in the following organometallic compounds: (a) Alkyl and Aryl derivatives, (b) Carbenes and Carbynes, (c) Alkene complexes, (d) Alkyne complexes, (e) Allyl complexes, (f) Cyclopentadiene complexes and (g) Arene complexes (sandwich and half sandwich complexes) (vi) Sixteen electron rule and electron counting with examples. **Surface Chemistry and Colloids:** (15 Lectures) The colloidal state (Introduction, classification and the colloidal systems); structural characteristics; preparation and purification of the colloidal systems; Kinetic properties: The motion of the particle in liquid media; Brownian motion and translational diffusion; The ultracentrifuge; Osmotic pressure; Rotary Brownian motion; Optical properties: Optical and electron microscope; light scattering Liquid gas, liquid-liquid interfaces; Surface and interfacial tensions; Adsorption and orientation at interfaces; association colloids-micelle formation; spreading; monomolecular films; The solid-gas interface; Adsorption of gases and vapors on solids; Composition and structure of solid surfaces; The solid liquid interface; contact angle-wetting; Ore flotation; Detergency; Adsorption from solution: Charged Interfaces: The electric double layer; Electro kinetic phenomena; Electro kinetic theory; Colloid Stability: Lyophobic sold; systems containing lyophilic material; stability control; Rheology;	

		Introduction; Viscosity; Non-Newtonian flow; Viscoelasticity; Emulsion and foams: Oil in water and water in oil emulsion; foams **Reference Books:** • A. W. Admson, Physical Chemistry of Surfaces, Wiley-Interscience (1990) ISBN 0-471-14873-3 • R. Aveyard and D. Haydon, An introduction to the principles of surface chemistry, Cambridge University Press (1973) ISBN-13: 978-0521201100 • P. Hiemenz, Principle of colloid and surface chemistry, Dekker (1986) ISBN 0-8247-9397-8 • E. Matijevic, Surface and colloid science, Wiley Inter science (1969) ISBN-13. 978-0306464560 • M. Rosen, Surfactants and Interfacial phenomena, Wiley (1978) ISBN-10. 0471478180 • T. Tadros, Surfactants, Academic Press (1984) ISBN-10. 0126821801	
3	Bio-nano Materials (CNN 503)	**Objective(s) of the course:** 1. Demonstrate knowledge on the biology and biotechnology and basics of nanoscale science and technology for their multifunctional applications. **Basics of Cell biology:** (15 Lectures) Basic structure of mammalian cell membrane, Cell Cycle, Different types of Cell receptors, Cell lines-Cancerous and Normal cell line, Primary and secondary cell line, Endocytosis and Exocytosis, Reticulo endothelial system (RES), Proteins structure-primary, secondary, tertiary and quaternary structure, Enzymes - Mechanism of actions - enzyme kinetics - Regulation of activities -Bioenergetics -Role of ATP – Biological oxidation - Respiratory chain and oxidative phosphorylation, Enzymes structure w.r.t metal part, prosthetic group (Metalloenzymes). Antigen-Antibody based assays-Elisa. **Nanobiomaterials and Biocompatibility:** (15 Lectures) Surface and Bulk Properties of Bio materials -Nanobiomaterials - NanoCeramics - Nanopolymers - Nano Silica - Hydroxy apatite – Carbon Based nanomaterials, Surface modification - Textured and Porous Materials – Surface immobilized biomolecules - Cell-biomaterial interactions- immune response - In Vitro and In Vivo assessment of tissue compatibility. **Structural & amp; Functional Principles of Bionanotechnology:** (15 Lectures) Carbohydrates – Biological significance, Lipid Bilayers- Liposomes - Neosomes-Phytosomes, Polysacharides - Peptides -Nucleic acids -DNA scaffolds -Enzymes- Biomolecular motors, Immunotoxins – Membrane transporters and pumps - Antibodies - monoclonal Antibodies - immunoconjugates –limitations of natural biomolecules. **Nanobio-Analytics:** (15 Lectures) Luminescent Quantum Dots for Biological Labeling –Nanoparticle Molecular Labels - Surface Biology: Analysis of Biomolecular Structure by Atomic Force Microscopy and Molecular Pulling - Force Spectroscopy -Biofunctionalized Nanoparticles for Surface - Enhanced Raman	4

		Scattering and Surface Plasmon Resonance - Bioconjugated Silica Nanoparticles for Bioanalytical Applications **Reference Books:** • Nanobiotechnology: Concepts, Applications and Perspectives by Niemeyer C. M., Wiley, VCH, 2006. ISBN: 978-3-527-30658-9 • Bionanotechnology by David S Goodsell, John Wiley & Sons, 2004. ISBN-13: 978-0471417194 • Bio-Nanotechnology: A Revolution in Food, Biomedical and Health Sciences by Debasis Bagchi, Manashi Bagchi, Hiroyoshi Moriyama, Fereidoon Shahidi, Wiley-Blackwell, 2013. ISBN-10. 0470670371 • Biomaterials Science: An Introduction to Materials in Medicine by Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E. Lemons, Academic Press, 2012. ISBN-13: 978-0123746269	
4	Practical Course I (CNN 504)	**Objective(s) of the course:** 1. Demonstrate an ability to visualize and work on laboratory and multidisciplinary tasks including material science, physics, chemistry and nano-biotechnology. 2. Develop confidence for self-education and ability for life-long learning. • Understanding hydrogen spectra using Rydberg's experiment. • Measuring magneto-resistance of a semiconductor material. • To determine dielectric constants of gases, liquids and solids. • Measuring conductivity of a material using two probe and four probe techniques. • Verification of Ostwald's dilution low and determination of the dissociation contact of a weak monobasic acid conductometrically. • Study of the effect of substituent on dissociation contact of acetic acid conductometrically. • Determination of concentrations and amounts of iodide, bromide and chloride in mixture by potentiometric titration with silver nitrate. • Lime Stome Ore: Loss on ignition; Ga by ETDA method. • Haematite Ore: Acid insoluble residue; Fe by redox titration. • To determine the mean ionic activity coefficient of zinc chloride by emf method. • To estimate the amount of hydrochloric acid and acetic acid in a mixture by titration with an alkali using a pH meter. • Inorganic Preparations of Bis-(tetraethylammonium) tetrachloro Cuprate (II) $(Et_4N)_2$ $[CuCl_4]$. • One step preparations (1.0 g scale) of Bromobenzene to p-nitrobromobenzene. • To determine amount of Cr(III) and Fe(II) individually in a mixture of the two by titration with EDTA. • Determination of the formlula of silver-ammonia complex by potentiometric method.	2

5	RM (CNN 506)	**Objective(s) of the subject:** 1. To provide research legitimacy and provides scientifically sound findings. 2. To plan and describe research to achieve and explain why to pursue it. **Foundations of Research:** (15 Lectures) Meaning, Objectives, Motivation, Utility. Concept of theory, empiricism, deductive and inductive theory. Characteristics of scientific method Understanding the language of Research - Concept, Construct, Definition, Variable. Research Process. Problem Identification & Formulation - Research Question Investigation Question -Measurement Issues - Hypothesis - Qualities of a good Hypothesis, Null Hypothesis & Alternative Hypothesis. Hypothesis Testing - Logic & Importance. **Research Design:** (15 Lectures) Concept and Importance in Research - Features of a good research design - Exploratory Research Design - concept, types and uses, Descriptive Research Designs concept, types and uses. Experimental Design: Concept of Independent & Dependent variables. Qualitative and Quantitative Research: Qualitative research Quantitative research Concept of measurement, causality, generalization, replication, Merging the two approaches. **Measurement:** (15 Lectures) Concept of measurement- what is measured? Problems in measurement in research- Validity and Reliability. Levels of measurement, Nominal, Ordinal, Interval, Ratio. Sampling: Concepts of Statistical Population, Sample, Sampling Frame, Sampling Error, Sample Size, Non Response. Characteristics of a good sample. Probability Sample- Simple Random Sample, Systematic Sample, Stratified Random Sample & Multi-stage sampling. Determining size of the sample Practical considerations in sampling and sample size. Data Preparation - Univariate analysis (frequency tables, bar charts, pie charts, percentages), Bivariate analysis-Cross tabulations and Chisquare test including testing hypothesis of association. **Interpretation of Data and Paper Writing**: (15 Lectures) Layout of a Research Paper, Journals in Computer Science, Impact factor of Journals, When and where to publish? Ethical issues related to publishing, Plagiarism and Self-Plagiarism. Use of Encyclopedias, Research Guides, Handbook etc., Academic Databases for Computer Science Discipline. Use of tools I techniques for Research: methods to search required information effectively, Reference Management Software like Zotero/ Mendeley, Software for paper formatting like LaTeX/ MS Office, Software for detection of Plagiarism etc. **Reference Books** • Research Methodology by Dr. Shefali Pandya, APH Publishing Corporation, 2012. ISBN: 9788131316054 • Business Research Methods- Donald Cooper & Pamela Schindler, TMGH, 9 th editions. ISBN-13: 978-0073521503 • Research Methodology- C. R. Kothari, New Age International Publisher, 2004. 2 nd edition. ISBN (13) : 978-81-224-2488-1	4

		• Business Research Methods- Alan Bryman & Emma Bell, Oxford University Press. ISBN-13: 978-0199583409	
Elective Courses (Any One)			
6	Essential Mathematics (CNN 505-A)	**Objective(s) of the course:** 1. Understand and apply mathematical techniques for describing and deeper understanding of material science. **Functions and Trigonometry:** (15 Lectures) Sets and functions, types of functions, some important functions and their properties, basics of trigonometry, trigonometric functions, trigonometric identities, inverse trigonometric functions **Differential and Integral Calculus:** (15 Lecture) Concept of limit and its properties, concept of derivatives, derivatives of important functions, differential identities, methods to find derivatives, concept of integration, integral identities, methods to find integration, different types of differential equations, methods to solve differential equations, concepts of partial derivatives **Complex numbers:** (15 Lecture) Concept of complex numbers, properties and identities, Argand diagram, modulus and argument in polar form, DeMoivre's theorem, algebra of complex numbers **Vectors and vector calculus:** (15 Lecture) Scalars and vectors, magnitude of a vector, properties of vectors, vector products and their properties, different co-ordinate systems, concept of del operator, gradient, divergence and curl of fields, concept of Laplacian operator **Reference books:** • Mathematical methods for Physics and engineering –by Riley, Hobson and Bence. ISBN-10. 0521679710. • Schaum's outline series on complex numbers. ISBN-13. 978-0071615693 • Schaum's outline series on vector calculus. ISBN-10. 007060228X	4
7	Numerical recipes methods for data analysis using python (CNN 505-B)	**Objective(s) of the cource:** 1. Understand and apply inter-disciplinary concepts and computational simulation for understanding and describing the natural phenomenon. **Fundamental concepts:** (15 Lectures) Introduction to Matrices, addition, subtraction, multiplication of matrices, concept of determinants, propeties of determinants, eigne values and eigenvectors; concept of probability, conditional probability, independence, random variables, distribution functions for random variables: normal, bionomial, Poisson; concept of series, Fourier series, Fourier transform of important functions, their physical interpretation **Data analysis:** (15 Lectures) Curve fitting for single and multi-variable data, single and multivariate regression, cost function, gradient descent, optimization; numerical interpolation, linear interpolation, cubic spline interpolation, finding roots of an equation, bisection method, Newton- Rapson method, Numerical differentiation and Numerical integration	4

		Python programming basics: (15 Lectures) Libraries like NumPy, Matplotlib, Scipy, Variables, Matrix operations, conditional statements, For loops, Plotting, Functions **Python programming exercise:** (15 Lectures) Python coding using Google Colab, Anaconda Spyder, Jupitor Notebook, Implementation of python code for single and multivariave regression, interpolation and roots of an equation. **Reference Books** • Schaum's outline series on linear algebra and matrices, McGraw Hill ISBN: 978-1-26-001144-9 • Schaum's outline series on Fourier transforms, McGraw Hill ISBN-13. 978-0070602199 • Introductory methods of Numerical Methods by S. S. Sastry, ISBN-978-81-203-4592-8 • PHI Learning Numerical Python by R. Johansson, Apress publications ISBN-13: 978-1484205549	
			Total Credits 22

Semester II

Mandatory Courses

Sr. No.	Course Name and Code	Proposed syllabus	Credits
1	Fundamentals of Nanomaterials (CNN 511)	**Objective(s) of the course:** 1. Provide exposure to advanced experimental/ theoretical methods for measurement, observation, and fundamental understanding of phenomenon at nanoscale and nanosystems. **Nanomaterials:** (15 Lectures) Introduction (History of Nanotechnology, Feynman's vision on Nano Science & technology, bulk vs nanomaterials. Central importance of nanoscale morphology - small things making big differences, nanotechnology as natures technology, clusters and magic numbers, nanoscale architecture. Recent developments, challenges and future prospects of nanomaterials) Fundamentals of Nanomaterials (Types of Nanomaterials, definition of nanoscale, surfaces and particle size, surface energy and surface tension and relation to size, phase transformation in nanomaterials, specific heat and heat capacity of nanomaterials, mechanical properties of nanomaterials, and optical properties of nanomaterials, electrical and magnetic properties of nanomaterials. Inclusion and importance of surface energy, equations of thermodynamics with surface energy Equilibrium Particle size, internal pressure and stability, nucleation processes. Kinetics of reactions at nanoscale, Diffusion at nanoscale, ripening among nano-precipitates) **Solid State Phenomena At Nanoscale:** (15 Lectures) Phonons, heat capacity: thermal energy of a harmonic oscillator, specific heat capacity: Debye and Einstein models, anharmonicity and thermal expansion, heat conduction by phonons. Magnetism, dielectrics and superconductivity. Finite solids and nanostructures, Phonons in nanomaterials, surface plasmons in metal nanostructures, nano sized magnetic domains, magnetic tunnel junctions and magneto-resistance. **Classification based on the dimensionality**: **Zero-dimensional nanostructures:** (15 Lectures) Metal, semiconductor and oxide nanoparticles. One-dimensional nanostructures: nanowires and nanorods, Two-dimensional nanostructures: Thin films, Three-dimensional nanomaterials, Special Nanomaterials: Carbon fullerenes and carbon nanotubes, micro and mesoporous materials, core-shell structures, organic-inorganic hybrids. Emerging Applications (in the field of nano-medicine, nano-electronic, nanoenergy, environmental, agriculture, food and defense with suitable examples as per ongoing developments in the field) **Reference Books:** • K. J Klabunde, R. M. Richards, Nanoscale Materials in Chemistry, 2nd Ed., Wiley, 2009. ISBN 978-0-470-22270-6 • T. Pradeep, A text book of Nano Science and Technology, Tata McGraw-Hill Education, 2012. ISBN-10. 1259007324 • G. Cao and Y.Wang, Nanostructures and Nanomaterials, 2nd Ed., Imperial College Press, 2004. ISBN-13 978-9814324557	4

		• R. Kelsall, I.Hamley and M. Geoghegan, Nanoscale Science and Technology, Wiley, 2005. ISBN-10. 0470850868 • G. Schmidt, Nanoparticles: from Theory to applications, Wiley-VCH, 2004 ISBN-13. 978-3527325894 • Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd., 2005. ISBN 0-470-85086-8	
2	Experimental Methods (CNN 512)	**Objective(s) of the course:** 1. Project their skill in various PVD and CVD system to synthesize nanomaterials in their bulk and thin film forms. **Fundamentals of Vacuum Technology and Surface Physics:** (15 lectures) Vacuum Nomenclature and Definitions, free gas, volume, pressure, pressure measurements, molecular processes, kinetic theory of gases, gas flows, mean free path, conductance, throughput, flow calculations, surface physics and it relation to vacuum sciences. Technology of vacuum pumps (diaphragm pumps, vacuum blowers, Roughing pumps, Sorption pumps, Scroll pumps, Blowers etc), High & Ultrahigh Vacuum Pumps (Oil Diffusion pumps, Turbo molecular pumps, Cryo-pumps, Ion Getter pumps/ Titanium sublimation pumps, **Vacuum systems, design, components and its measurements:** (15 lectures) Selection of vacuum valves, suitable materials for vacuum systems and hardware (view ports, construction materials, etc.), flanges and components (Flanges, Valves, etc.), Feedthroughs, magnetic-fluid-sealed rotary motion feedthroughs, preparation and cleaning of vacuum surfaces. Measurement systems for vacuum (Bourdon gauge, Capacitance manometer, Thermocouple Gauge, Pirani Gauge, Penning/Cold Cathode Gauge, Hot Cathode Gauge, McLeod Gauge, Residual Gas Analyser), Mass Analysis and Partial Pressure Measurements, Practical Aspects of Vacuum System Mass Spectrometers, Mass Flow Measurement and Control, Helium Leak Detection. **Vacuum Applications:** (15 Lectures) High vacuum based process, sputtering, plasma cleaning and etching, generation of electrons, generation of X-rays, generation of high energy particle, etc., roll to roll vacuum coating, etc. **Overview of other Techniques for materials characterization:** (15 Lectures) X-Ray and Neutron powder diffraction, electron spectroscopy for Chemical Analysis, ellipsometry for Thin Film Analysis, electrical conductivity of metals and semiconductors, Seebeck coefficient in metals and semiconductors, dielectric properties, magnetic properties, small angle X-ray scattering, dynamic light scattering techniques, **Reference Books** • Handbook of Vacuum Technology, Editor(s): Karl Jousten, ISBN:9783527413386 • Vacuum Technology and Vacuum Design Handbook for Accelerator Technicians, David Garton, ISBN number: 192126814X • Vacuum technology practice for scientific instruments, Nagamitsu Yoshimura, ISBN 978-3-540-74432-0	4

		• Fundamentals of Vacuum Technology, Dr. Walter Umrath, Leybold	
3	Micro-nano fabrication techniques (CNN 513)	**Objective(s) of the course:** 1. Project skills in various lithography techniques followed by and nano/micro fabrication tools. 2. To make aware about NEMS/MEMS systems widely used in various technologies. **Basic Micro-fabrication Techniques:** (15 lectures) Lithography by photons and charged particles: Optical projection lithography, Optical lithography at short wavelengths (deep UV, Extreme UV, X-rays), near field optical lithography, Interferometry optical lithography, Massless Optical Lithography, Focusing Charged particle beam, Charged particle optics, Sources (electrons, ions), Scattering and proximity effect, E-Beam Lithography (E-BEL), Focused Ion beam Lithography (FIB), Resists and materials, Thin-Film Deposition and Doping, Substrate Bonding, etc. **Mask making and nano Fabrication by Scanning Probes and self-assembly techniques:** (15 Lectures) Type of mask, practices to fabricate masks, principles of SPM, Exposure of Resists, Local oxidation lithography, Dip-pen lithography, Self-assembly process, Guided Self Assembly, self-assembly using Surface Forces, self-assembly using electrostatic forces, self-assembly using magnetic force, Colloidal Inorganic Nanocrystals: Synthesis and Controlled Assembly, Self-Assembled DNA Nanostructures and DNA Devices, Building blocks of future nano systems (DNA scaffold, Carbon Nanotubes, Black co-polymers, Porous Alumina), Soft lithography, Template Manufacturing **3D printing and case studies**: (15 Lectures) Bio printers, Robot printers, semiconductor printers, 3D Subtractive Printing with Ultrashort Laser Pulses, 3D Additive Printing with Ultrashort Laser Pulses, New Emerging Techniques **Micro-Nano Electrochemical Systems and Fabrication:** (15 lectures) Bulk Micromachining, Surface Micromachining, CNC milling and micro-machines, IHigh-Aspect-Ratio Micromachining, MEMS-NEMS fabrication, New Emerging Techniques **Reference Books:** • Nanofabrication: Principles, Capabilities and Limits by Zheng Cui,, Springer. ISBN 0-521-78019-5 • Nanofabrication fundaments and applications by A. A. Tseng, World Scientific ISBN 10: 9812705422 • Handbook of Nanofabrication by G. Wiederrecht, Academic Press ISBN: 9780123751768	4
4	Practical Course II (CNN 514)	**Objective(s) of the course:** 1. To develop understanding towards the working of various electronic/semiconductor devices. 2. Demonstrate an ability to analyze various electric circuits, design and develop new electronic circuit. • Basic Electronic Circuits (The Voltage Divider, Capacitors, AC and DC Circuits, Impedance). • Common Laboratory Equipment (wires and cables, DC and AC power supply, Waveform Generators, Oscilloscopes). • Design of a Regulated Power Supply.	2

		• Wein's Bridge and Phase shift. • P–N Junction & Zener Diode Characteristics (Forward & Reverse biased) • Input & Output Transistor Characteristics (Common Emitter, Base & Collector). • FET Characteristics. • MOSFET Characteristics. • Deposition of thin film by RF and DC sputtering • Deposition of thin film by Pulsed Laser Deposition • Leak Detection in vacuum systems using Helium Leak Detector.	
5	OJT (CNN 516)	**Objective(s) of the course:** 1. To make students aware about the industrial requirements and how they function. 2. To provide internship to students based on their interests. **Companies suggests for on field training** • Excel Instrument, Gala No.9&10, Bldg No 2, Dias Industrial Complex, Sativali Naka, Vasai (East), Palghar-401208, Maharashtra (India). • Aditya Birla Science And Technology Co. Pvt. Ltd Plot No.1 & 1-A/1, MIDC Taloja, Panvel, Navi Mumbai – 410208. • Oerlikon Balzers Coating India Pvt. Ltd. EL-22, J Block, MIDC, Bhosari, Pune, Maharashtra 411026. • Surface Modification Technologies (SMT) Pvt. Ltd. Unit 9, Emrald Premises, Behind Modi Hyundai, Sativali Road, Vasai Road – (East), Dist. Palghar, Maharashtra - 401208. • ANTS Ceramics (P) Ltd. Unit No. 1, New Jivdani Industrial Estate No. 1 Dhumal Nagar, Off Western Express Highway, Near Waliv, Vasai (E) Thane - 401208, Maharashtra, India. • Cipla Limited Cipla House, Peninsula Business Park, Ganpatrao Kadam Marg, Lower Parel, Mumbai-400 013. • Deepak Fertilizers & Petrochemicals Ltd. Plot K1, Midc Industrial Area, P.O., Taloja - 410208, Maharashtra.	4
Elective Courses (Any one)			
6	Nanomaterial synthesis techniques :PVD and CVD (CNN 515-A)	**Objective(s) of the course:** 1. To develop understanding towards various nanomaterial synthesis process. **Vapor Deposition Methods:** (15 lectures) Thermal Evaporation, Cathodic vapor arc deposition, Electron-beam physical, vapor deposition, Pulsed Laser Deposition, laser pyrolysis, Molecular Beam Epitaxy, Sputtering (DC, RF & Magnetron sputtering), Atomic Layer Epitaxy and Self-assembly technique, layer deposition ball milling, Spray pyrolysis, Microwave irradiation, Gamma radiation, ion implantation, Electro-spinning. **Nanomaterial synthesis using PVD techniques:** (15 Lectures) Designing of advanced integrated nanocomposites, preparation of quantum dots, nano wires and films, preparation of single-walled and multi-walled nanotubes, recent developments	4

		Chemical Vapor Deposition Methods: (15 lectures) MOCVD technique, Plasma / Sputtering / Hot-Wire Plasma Enhanced CVD method, Solution growth techniques of 1D-nanostructures- Synthesis of metallic, semiconducting and oxide nanoparticles, Nanowires, nanotubes and nanorods;2D-nanostructures-thin films-Nanoparticles through homogeneous & heterogenous nucleation in solution, co-precipitation, chemical reduction, hydrothermal and solvothermal synthesis, sonochemical synthesis, polyol method, sol-gel synthesis, micelles and microemulsion assisted synthesis, photolysis, radiolysis, thermal decomposition, self-assembly methods and Langmuir Blodgett (LB) method. Template-based synthesis (electrochemical, electrophoretic, Melt and solution, CVD, ALD), Gas Phase Synthesis of Nano powders: Vapor (or solution) – liquid – solid (VLS or SLS) growth – the Need for Gas/vapor State Processing – Main Stages of Gas Phase Synthesis Evaporation. **Special features of nanoscale growth:** (15 Lectures) Thermodynamics of Phase Transitions – triggering the Phase Transition – fundamentals of nucleation growth – Controlling Nucleation & Growth – Size Control of the Nanometric State –Aggregation – Stability of Colloidal Dispersions – Spontaneous Condensation of Nanoparticles: Homogeneous Nucleation – Spinodal decomposition – Other undesirable Post-Condensation Effects – Nanoparticles' morphology **Reference Books:** • Handbook of Physical Vapor Deposition (PVD) Processing, Donald M. Mattox, ISBN 978-0-8155-2037-5 • Physical Vapor Deposition of Thin Films, John E. Mahan ISBN: 978-0-471-33001-1 • Chemical Vapour Deposition Growth processes on an atomic level, Karin Larsson ISBN: 978-0-7503-3107-4 • Chemical Vapour Deposition (CVD) Advances, Technology and Applications, Edited By Kwang-Leong Choy ISBN 9780367780111	
7	Electronics and circuit designing (CNN 515-B)	**Objective(s) of the course:** 1. Demonstrate an ability to analyze various electric circuits. 2. Develop confidence in students to design and develop their own electronic circuit essential to develop in house nanotechnologies. **Analog Circuit Design:** (15 Lecture) Basic DC circuits (voltage, current, resistance and Ohms law), Ideal current and voltage source, Kirchhoff's laws (voltage, current), circuit analysis, resistors (serious, parallel, network, measuring internal resistance, load line, etc.), Capacitor (construction, Kirchhoff's law and capacitor, time domain, capacitance in series and parallel), Inductor, Switches and relays, generators, The Electric Circuit Analogy, The Amplifier Concept, **Circuit Analysis:** (15 Lectures) Thevenin's Theorem, Norton's Theorem, The Voltage Divider Design, The Current Divider Design, The Passive Adder, The Wheatstone Bridge, Digital Logic Interface, RC Lowpass Network, Parallel Resonance, the Q Factor, Bandwidth of a Resonant Circuit, The Ideal Transformer, Impedance **The Operational Amplifier:** (15 Lectures) Miller Effect, Feedback Capacitance, The Op-Amp Adder, Offset Generator, Non-Inverting Adder, Sign Changer (Inverter), Switchable Sign	4

		Changer, The subtractor, The Difference Amplifier, The Instrumentation Amplifier, Universal Amplifier, Current to Voltage Converter, Integrator, Inverting, Integrator in the Frequency Domain, Differentiator, Application (Spring-Mass Simulation, Booster Stage, etc.) **The power supplies:** (15 Lectures) AC Power Distribution, Power Supply Configuration, Multiple Voltage Supplies, Rectifier-Filter Configurations (half wave, dual polarity half wave, Full-Wave Centre Tapped, Full Wave Bridge, Full Wave Bridge, Dual Polarity), The Inductor Filter, Series and Shunt Voltage Regulators, Feedback Voltage Regulator, Three-terminal Linear Regulator, Switching Regulator **Reference Books:** • Analog Circuit Design, Peter D. Hiscocks, ISBN 978-0-9867235-0-6 • Electronic Principles, Albert Paul Malvino, ISBN: 9780070634244 • Analog Circuit Design, Jim Williams, ISBN 0-7506-9640-0	
8	Computing nanomaterials (CNN 515-C)	**Objective(s) of the course:** 1. To study, design, operation, analysis and optimization of Nano-scale systems 2. Build the aptitude to perceive, measure, operate and build materials at the nanometer scale, the size of atoms and molecules. **Basic Concepts and Theoretical Background:** (15 Lectures) Introduction and basic concepts: Theoretical background, basic equations for interacting electrons and nuclei, Coulomb interaction in condensed matter, Independent electron approximations, periodic solids and electron bands, structures of crystals: lattice + basis, the reciprocal lattice and Brillouin zone, excitations and the Bloch theorem. The quantum theory of bonding: The Hamiltonian formulation, Dirac notation, electronic wave function, Schrödinger equation. **Quantum Mechanics of Materials:** (15 Lectures) Central field approximation, Hamiltonian of the solid, Born-Oppenheimer approximation, hydrogen atom and molecule. Hartree-Fock method: Coulomb and exchange operator, Fock operator, the HartreeFock Hamiltonian, basis set, charge density, the self-consistent field (SCF) procedure, expectation value. Density functional theory: Exact formulation, approximations, choice of basis functions, essential machinery of a place-wave DFT code, energy minimization and dynamics. Semi-empirical tight binding methods: Linear combination of atomic orbitals (LCAO), Hamiltonian and overlap matrices, Slater-Koster parameters for two-center integral, tight binding to empirical atomistic models. **Molecular Statics :** (15 Lectures) The potential energy landscapes. Energy minimization: Generic nonlinear minimization, steepest descent, line minimization, conjugate method, Newton-Raphson method. Saddle points and transition paths: Nudged elastic band method Implementing molecular statics: Neighbor list, periodic boundary condition, applying stress and pressure, boundary conditions on atoms. Application to crystals and crystalline defects: Cohesive energy of an infinite crystal, crystal defects (vacancies, surfaces, interfaces, dislocations). **Modelling and Simulations of Materials:** (15 Lecture) Model systems and interatomic potentials, Molecular Dynamics: Equations of motion for atomic systems, the basic machinery and finite difference	4

		methods, time integration algorithm, starting a simulation, simulation of microcanonical (NVE) and canonical ensemble (NVT), controlling the system (temperature, pressure), thermostats and barostats, equilibration, running, measuring and analyzing MD simulation data, measurement of statistical quantities, estimating errors. **Reference Books:** • Condensed Matter in a Nutshell, G. D. Mahan, Princeton University Press, Princeton and Oxford (2011). ISBN-10. 0691140162 • Modern Quantum Chemistry – Introduction to Advanced Electronics Structure Theory, A Szabo and N. S. Oslund, Dover Publications Inc., Mineola, New York, (1989). ISBN-10, 0486691861 • Electronic Structure Calculations for Solids and Molecules – Theory and Computational Methods, Jorge Kohanoff, Cambridge University Press, 1 edition (2006). ISBN: 9780511755613 • Modelling materials – Continuum, Atomistic, Multiscale Techniques, E. B. Tadmor and R. E. Miller, Cambridge University Press, New York (2011). ISBN: 9781139003582 • Computer Simulation of Liquids, M. P. Allen and D. J. Tildesley, Clarendon Press –Oxford, (1991). ISBN-13: 978-0198556459 • Understanding Molecular Simulations, D. Frenkel and B. Smit, Academic Press, (2002). ISBN-13: 978-0122673511	
9	Thermodynamics and catalysis of nanomaterials (CNN 515-D)	**Objective(s) of the subject:** 1. To make student aware about the catalytic performances, synthesis and characterization of nanocatalysts, 2. It will also help them to examine and explore the current state of the art and pointing the way towards new avenues of research in this field. **Thermodynamics:** (15 Lectures) First Law of Thermodynamics, heat, work, heat capacity, enthalpy and internal energy, Second Law of Thermodynamics – Entropy and Criterion for Equilibrium –Statistical interpretation of entropy – Boltzmann equation. Auxiliary Functions–Thermodynamic Relations– Maxwell"s Equations– Gibbs - Helmholtz Equation– Examples – Heat capacity, enthalpy, entropy and the third law of Thermodynamics- First, second, and third laws of thermodynamics as applied to nanoscale systems **Phase Equillibria:** (15 Lectures) Phase equilibrium in a one – component system – Composition and Phase diagrams of binary Systems – Criteria for Phase stability – Thermodynamics and kinetics of phase transformations- Homogeneous nucleation- Heterogeneous nucleation. Physical phenomena of small systems - nano-crystals, macromolecules, thermodynamics and physical properties of long chain molecules and molecular structures **Concepts of catalysis:** (15 Lectures) Introduction to catalysis, classifications, heterogeneous catalysis, reaction on the solid surfaces, adsorption isotherms, physisorption and chemisorptions, reaction mechanism and kinetics of the heterogeneous catalytic reactions, activation energy (Arrhenius equation, Eyring equation). Catalytic activity (bulk and nanoscale), catalytic activity	4

		determination for metal/metal oxide nanostructures. Langmuir-Hinshelwood mechanism for nanocatalyst, Mass transport, diffusion controlled process, catalytic efficiency and turnover frequency, inhibition. Application of metal nanoparticles in organic reactions (Heck and Suzuki-Maurya reactions), environmental remediation. Nanoarchitecture (regular materials and nano materials), Size, Shape and Surface Chemistry of Nanoparticles, Properties of Nanomaterials on Catalysis, Metallic Nanoparticles, Metal Oxide Nanoparticles, Carbon Nanoparticles, Assembling Strategies to Control Active Site Location, Nanocatalysis: Applications in Chemical Industry (Fuel Cell, Exhaust Catalysts, Gas Sensors, Photocatalysis, Enantioselective Catalysis, etc.), Photocatalyst (Electronics structure and photoabsorption, Kinetics and photocatalytic activity, Jablonskii diagram, Structure of photocatalysts and solar spectrum analysis. Fundamental understanding of semiconductor interfaces, Principles and relevance to photoelectrochemical and photocatalysis mechanism, Properties of good photocatalysts, Advantages of photocatalysts, types of photocatalysts, carbonaceous and plasmonic photocatalysts.) **Carbon and selected nanomaterials as catalyst (a case study):** (15 Lectures) Carbon molecules, nature of the carbon bond, new carbon structures, discovery of C60-structure of C60 and its crystal, From a Graphene Sheet to a Nanotube, Single wall and Multi walled Nanotubes, Zigzag and Armchair Nanotubes, Nomenclature, Euler's Theorem, Growth Mechanisms; Production and Purification- Graphene and other carbon nanomaterials: for various catalytic Applications. **Reference Books** • Carbon Nanotubes: Properties and Applications- Michael J. O'Connell. ISBN-13. 978-0849327483 • Nanoparticles in Catalysis, Karine Philippot, Alain Roucoux ISBN: 9783527821761 • Nanocatalysis Applications and Technologies, Vanesa Calvino-Casilda, Antonio José López-Peinado, Rosa María Martín-Aranda, Elena Pérez Mayoral ISBN 9780367780258 • Nanotechnology in Catalysis 3 (Nanostructure Science and Technology), Bing Zhou, Scott Han, Robert Raja, Gabor A. Somorjai ISBN-10 0387346872	
		Total Credits	22

Annexure I
University of Mumbai
Two Year Degree Course of M.Sc. (Nanosciences and Nanotechnology)
As per Choice Based Credit System (CBCS)
(With effect from the academic year 2023-2024)
Examination pattern for Semester I and II

Semester I:

a) Theory Paper : 100 marks for each paper (Total theory papers 5)
- **i) Internal examination** : Total marks 50 (in each theory paper)
- **ii) External examination** : Total marks 50 (in each theory paper) Duration: 2 1/2 Hours
  1) Total number of questions to be framed for theory paper in external examination is 7 of 10 marks each.
  2) Out of total 7 questions, students are required to attempt **any five** questions.

b) Practical Paper : 50 marks for one paper (Cr. 2)
(Out of total 50 marks in two credits practical, 40 marks for practical examination, 10 marks for journal writing and viva.)

c) Marking system:
- i) Total marks for theory: 4 Credits *5 theory papers =20 credits
- ii) Total marks for practical: 2 credits for one practical papers
- **iii) Grand Total for Semester I is 22 credits**

Semester II

a) Theory Paper : 100 marks for each paper (Total theory papers 5)
- **i) Internal examination** : Total marks 50 (in each theory paper)
- **ii) External examination** : Total marks 50 (in each theory paper) Duration: 2 1/2 Hours
  1) Total number of questions to be framed for theory paper in external examination is 7 of 10 marks each.
  2) Out of total 7 questions, students are required to attempt **any five** questions.

b) Practical Paper : 50 marks for one paper (Cr. 2)
(Out of total 50 marks in two credits practical, 40 marks for practical examination, 10 marks for journal writing and viva.)

c) On job Training : 100 Marks for On Job Training (Cr. 4)
The evaluation of on job training will be done as per the guidelines provided by the University of Mumbai, for e.g. students have
1) OJT completion certificate from the industries
2) Every individuals have to submit the report about visit
3) They have to identify at least one best practices the industry is following
4) They have to identify at least one problem the industry is facing along with the possible solutions.

c) Marking system:
- i) Total marks for theory: 4 Credits *4 theory papers =16 credits
- ii) Total marks for practical: 2 credits for one practical
- iii) On job training: 4 Credits
- **iv) Grand Total for Semester II = 22 credits**

Total credits earned at the end M.Sc. first year (Semester I and Semester II) would be 44.

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University of Mumbai

University of Mumbai NCNNUM

Letter Grades and Grade Points

Semester GPA/ Program CGPA/Semester	% Marks	Letter Grade Result
9.00-10.00	90.0-100.0	O (Outstanding)
8.00≤9.00	80.0≤90.0	A+ (Excellent)
7.00≤8.00	70.0≤80.0	A (Very Good)
6.00≤7.00	60.0≤70.0	B+ (Good)
5.50≤6.00	55.0≤60.0	B (Above Average)
5.00≤5.50	50.0≤55.0	C (Average)
4.00≤5.00	40.0≤50.0	P (Pass)
Below 4.00		F (Fail)
Ab (Absent)		Absent

Director
National Centre for Nanoscience and Nanotechnology
University of Mumbai

Syllabus

M.Sc. in (Nanosciences and Nanotechnology) (SEM I & II)

Team for creation of syllabus

Name	Name of Dept./Institute	Sign
Prof. Shivram Garje	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Suhas M. Jejurikar	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Pravin Walke	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Tushar Sant	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Kunjal Shah	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Bhavesh Sinha	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Kalpesh Bhavsar	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Prof. Balasaheb Nagare	Department of Physics, University of Mumbai	

Sign of HOD

Prof. Shivram Garje
National Center for Nanoscience and
Nanotechnology, University of Mumbai

DIRECTOR
National Center For Nanosciences &
Nanotechnology University of Mumbai

Sign of Dean

Prof. Shivram Garje
Science and Technology

Appendix B

Justification for M.Sc. (Nanosciences and Nanotechnology)

1.	Necessity for starting the course:	The two-year master's course in "Nanoscience and Nanotechnology" is designed with the focus to understand/develop technologies in sectors for e.g. optoelectronics, electronics, space, energy sectors, agriculture, medicinal, biotechnology, etc. The course proposed herewith provides a fundamental understanding towards the physical and chemical properties of these materials, methods to synthesize, characterize them. The micro and nanofabrication followed by hands on training provided to students on state of art instruments will provide enough confidence in the students to design/develop their own in house technologies.
2.	Whether the UGC has recommended the course:	Yes
3.	Whether all the courses have commenced from the academic year 2023-24	Yes
4.	The courses started by the University are self-financed, whether adequate number of eligible permanent faculties are available?:	University self-finance Adequate no. of permanent faculties: No
5.	To give details regarding the duration of the Course and is it possible to compress the course?:	Two years
6.	The intake capacity of each course and no. of admissions given in the current academic year:	Intake : 60 Students admitted current year : 30
7.	Opportunities of Employability / Employment available after undertaking these courses:	Semiconductor/electronics/optoelectronic industries, chemical and Pharma industries, Environmental sectors, Medical industries, etc.

Sign of Director

Prof. Shivram Garje
National center for Nanosciences and nanotechnology

Director
National Centre for Nanosciences and Nanotechnology
University of Mumbai

Sign of Dean,

Prof. Shivram Garje
Dean (Science)
University of Mumbai

University of Mumbai
NCNNUM