University of Mumbai

No. UG/ 30 of 2020-21

CIRCULAR:-

Attention of the Principals of the Affiliated Colleges, the Head University Departments and Directors of the recognized Institutions in Science & Technology Faculty is invited to this office circular No.UG/336 of 2018, dated 8th February, 2018 relating to the revised syllabus of M.Sc. in Nano-Sciences and Nano- Technology (Sem. I &II).

They are hereby informed that the recommendations made by the Ad-hoc Board of Studies in Nano Science and Nano Technology at its online meeting held on 9th July, 2020 vide Item No.1 and subsequently made by the Board of Deans at its meeting held on 20th July, 2020 vide item No. 26 have been accepted by the Academic Council at its meeting held on 23rd July, 2020 vide item No. 4.96 and that in accordance therewith, the revised syllabus as per the (CBCS) of M.Sc.(Part-I) (Sem.-I & II) in Nano Science and Nano Technology has been brought into force with effect from the academic year 2020 -21 accordingly. (The same is available on the University's website www.mu.ac.in).

(Dr. Vinod Patil)
I/c REGISTRAR

MUMBAI – 400 032
11th November, 2020

To

The Principals of the affiliated Colleges, the Head University Departments and Directors of the recognized Institutions in Science & Technology Faculty. (Circular No. UG/334 of 2017-18 dated 9th January, 2018.)

A.C/4.96/23/07/2020

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No. UG/ 30 -A of 2020-21 MUMBAI-400 032 11th November, 2020

Copy forwarded with Compliments for information to:-

1) The Dean, Faculty of Science & Technology,
2) The Chairman, Ad-hoc Board of Studies in Nano Science and Nano Technology,
3) The Director, Board of Examinations and Evaluation,
4) The Director, Board of Students Development,
5) The Co-ordinator, University Computerization Centre,

(Dr. Vinod Patil)
I/c REGISTRAR

Copy to :-

1. **The Director of Board of Student Development.,**
2. **The Deputy Registrar (Eligibility and Migration Section)**
3. **The Director of Students Welfare,**
4. **The Executive Secretary to the to the Vice-Chancellor,**
5. **The Pro-Vice-Chancellor**
6. **The Registrar and**
7. **The Assistant Registrar, Administrative sub-centers, Ratnagiri, Thane & Kalyan, for information.**

1. **The Director of Board of Examinations and Evaluation**
2. **The Finance and Accounts Officers**
3. **Record Section**
4. **Publications Section**
5. **The Deputy Registrar, Enrolment, Eligibility and Migration Section**
6. **The Deputy Registrar (Accounts Section), Vidyanagari**
7. **The Deputy Registrar, Affiliation Section**
8. **The Professor-cum- Director, Institute of Distance and Open Learning Education,**
9. **The Director University Computer Center (IDE Building), Vidyanagari,**
10. **The Deputy Registrar (Special Cell),**
11. **The Deputy Registrar, (PRO)**
12. **The Deputy Registrar, Academic Authorities Unit (1 copies) and**
13. **The Assistant Registrar, Executive Authorities Unit**

They are requested to treat this as action taken report on the concerned resolution adopted by the Academic Council referred to in the above circular and that on separate Action Taken Report will be sent in this connection.

1. **The Assistant Registrar Constituent Colleges Unit**
2. **BUCTU**
3. **The Deputy Accountant, Unit V**
4. **The In-charge Director, Centralize Computing Facility**
5. **The Receptionist**
6. **The Telephone Operator**
7. **The Secretary MUASA**
8. **The Superintendent, Post-Graduate Section**
9. **The Superintendent, Thesis Section**

for information.

AC_____
Item No. _____

UNIVERSITY OF MUMBAI

Program : M.Sc.

Course : Nanosciences and Nanotechnology

Syllabus for Semester:I and II

(Choice Based and Credit System with effect from the Academic year 2020-21)

AC_____
Item No. _____

UNIVERSITY OF MUMBAI

Syllabus for Approval

Sr. No.	Heading	Particulars
1	Title of the Course	M.Sc. in Nanosciences and Nanotechnology
2	Eligibility for Admission	The admissions of Indian candidates are through a national level entrance examination. Applicants seeking admission to this course must have a B.Sc. degree from recognized university having specialization in Physics, Chemistry, Life Sciences, Biotechnology, Botany, Zoology, Microbiology, and Geology with minimum second class.
3	Passing Marks	60 %
4	Ordinances / Regulations (if any)	
5	No. of Years / Semesters	2 Years (4 semesters)
6	Level	~~Certificate/Diploma/UG~~/PG **(Strike out which is not applicable)**
7	Pattern	Semester/~~Yearly~~ **(Strike out which is not applicable)**
8	Status	Revised/~~New /~~ **(Strike out which is not applicable)**
9	To be implemented from Academic Year	From Academic Year: 2020-2021

Date: July 16, 2020 Signature :

Prof. Prakash Mahanwar
Chairman of BoS
(Nanosciences and Nanotechnology)

Dr. AnuradhaMajumdar
Dean,
Science and Technology

PREAMBLE

In order to initiate awareness of research ongoing in the field of Nanosciences and nanotechnology, NCNNUM has introduced post-graduation course work entitled Masters of Science (Nanosciences and Nanotechnology). The course work designed/proposed herewith not only gives awareness to PG students towards the subject/technology but also provides flexibility to work in interdisciplinary manner to provide solutions for society problems in more scientific way. Understanding growing demands and the need to literate and motivate young generation towards the field of Nanosciences and Nanotechnology where the field has already reduced the gap in between scientific research and technological breakthroughs in various area including medical, space, military, communication technology etc.:

The revised course syllabus proposed herewith will achieve the necessary training and skills by next generation industry for students and engineers undertaking research, development and production in nanosciences and nanofabrication.

Dr. Anuradha Majumdar
(Dean, Science and Technology)

Prof. Shivram Garje
(Associate Dean, Science)

Name of Chairperson (BoS)	:	Prof. Mahanwar, ICT
Member(BoS)	:	Dr. AtulChaskar
Member (BoS)	:	Dr. SuhasJejurikar
Member (BoS)	:	Dr. PravinWalke

Semester I

Compulsory Theory Courses:

1. CNN-101 Essential Physics (4 Credits)
2. CNN-102 Essential Chemistry (4 Credits)
3. CNN-103 Essential Mathematics (4 Credits)
4. CNN-104 Essential Biology (4 Credits)

Compulsory practical Course:

1. CNN-111 Physics Practical (2 Credit)
2. CNN-112 Chemistry practical (2 Credit)
3. CNN-113 Biology practical (2 Credit)
4. CNN-114 Mathematics practical (2 Credit)

Semester II

Compulsory Theory Courses:

1. CNN-201 Solid State Physics and Thermodynamics (4 Credits)
2. CNN-202 Fundamentals of Nanomaterials (4 Credits)
3. CNN-203 Atoms, Molecules and Spectra's (4 Credits)
4. CNN-204 Experimental Methods (4 Credits)

Optional Theory Courses:

1. CNN-205 Nano biotechnology: Concepts, Applications & Tools (4 credits)
2. CNN-206 Nanotechnology in food and agriculture (4 credits)
3. CNN-207 Medical Nanotechnology (4 credits)
4. CNN-208 Nanotechnology –Environmental, Ethical & Economic Impact (4 credits)

Compulsory practical's Course:

1. CNN-211 Synthesis and Characterization of Nanomaterials I (2 Credit)
2. CNN-212 Synthesis and Characterization of Nanomaterials II (2 Credit)

Semester I

Course Code : CNN 101 **Compulsory Course**
Name of the course : Essential Physics
Credits : 4 **Total Lectures** : 60

Survey of Elementary Principles(15L)

Review of Newton's Laws of motion, Conservation laws, Motion of charged particles electric, magnetic and electromagnetic field, Mechanics of system of particles, Energy and momentum conservation by system of particles.Generalized coordinates, Constraints, Principle of virtual work, D'Alembert's Principle and Lagrange Equations.

Lagrangian formulation andHamiltonian dynamics(15 L)

Equivalence of Lagrange and newtons equations, Velocity dependent potential and Rayleigh dissipation function, Application of Lagrangian formulations (Single particle in space, Atwood's Machine, Time dependent constraints),Hamilton's principle and Lagrange Equations. Configuration space, techniques of calculus variation.

Elementary Atomic physics (15 L)

Particle like properties of radiation: Photoelectric Effect, Compton Effect, Dual Nature of Electromagnetic Radiation, photons, Wavelike properties of particle, The Wave-Particle Duality, Atomic Spectra, Bohr's Postulates, Bohr's Model, Atomic Energy States, Quantization Rules, Sommerfeld's Model, The Correspondence Principle.

Elementary Electronics (15 L)

Basic components and working principles of A.C. and D.C. circuits, Basics ideas of Diodes and Transistors, Digital Electronics-Logic gates, Logic gates and basic Boolean operations;

Reference books:

1. Classical Mechanics by H. Goldstein, C. Pool, and J. Safko; Addison Wesley
2. Classical Mechanics by P.V. Panat; Narosa publications
3. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles by R. Eisberg; John Wiley and Sons
4. Fundamentals of Molecular Spectroscopy by W. S. Struve, John Wiley and Sons
5. Fundamentals of Molecular Spectroscopy by C. N. Banwell, McGraw-Hill
6. Electronic Principles by A. Malvino and D. Bates
7. Quantum Chemistry by R. K. Prasad
8. Quantum Chemistry by I. N. Levine: Pearson Prentice Hall

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Course Code : CNN 102 **Compulsory Course**
Name of the course : Essential Chemistry
Credits : 4 **Total Lectures** : 60

Chemical Kinetics (15 L)

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 – Lindeman-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 (15 L)

Hybridisation: Derivation of wave functions for the following orbital hybridization types: sp (BeH2); sp2 (BF3); sp3 (CH4) 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. chloro-fluorides of phosphorous, fluoro-methane's, etc.

Organometallic Chemistry (15 L)

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) Alkyl complexes, (f) Cyclopentadiene complexes and (g) Arenes complexes (sandwich and half sandwich complexes) (vi) Sixteen electron rule and electron counting with examples.

Surface Chemistry and Colloids (15 L)

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 and 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; foams

Reference Books:

- A. W. Admson, Physical Chemistry of Surfaces, Wiley-Interscience (1990)
- R. Aveyard and D. Haydon, An introduction to the principles of surface chemistry, Cambridge University Press (1973)
- P. Hiemenz, Principle of colloid and surface chemistry, Dekker (1986)
- E. Matijevic, Surface and colloid science, Wiley Inter science (1969)
- M. Rosen, Surfactants and Interfacial phenomena, Wiley (1978)
- T. Tadros, Surfactants, Academic Press (1984)
- K. J. Laidter, Chemical Kinetics, Pearson Press
- McQuarine and Simon, Physical Chemistry: A Molecular Approach
- P. W. Atkinson, Physical Chemistry: ELBS with Oxford University Press
- I. N. Levine, Physical Chemistry: Mc-Grow Hill

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Course Code	**:** CNN 103	**Compulsory Course**	
Name of the course	**:** Essential Mathematics		
Credits	**:** 4	**Total Lectures**	**:** 60

Analysis and Linear Algebra (15L)

Comprehensive review of graduate level mathematics; One Variable calculus, Real and complex numbers, Differentiation, mean value theorem; Limits and Convergence of Sequences and series, continuity, Taylor series, McLaurin series, Fundamental theorem of calculus, Improper integrals, Integration

Linear Algebra: Vector Spaces (15L)

Basis and dimension, Linear transformations, Direct sums, products, Determinants, Matrices, Matrix algebra, Eigenvalues and Eigen vectors, Characteristic polynomial, Cayley- Hamilton theorem, Minimal polynomial, Algebraic geometric multiplicities, Diagonalization.

Trigonometry, applications of Fourier series and transforms(15L)

Introduction to basic concepts (Pythagoras theorem, ratios, functional forms), Trigonometric waveforms, (graphs of wavefunctions, propagation of wave, sinusoidal forms, waveform harmonics); Fourier series, transforms, properties of Fourier transforms

Functional Analysis, Probability and Statistics (15L)

Basic Topological concepts, metric spaces, normed linear spaces, Banach spaces, bounded linear functional and dual spaces, the Hahn-Banach Theorem, bounded linear operators, open-mapping theorem, closed graph theorem, the Banach- Steinhaus theorem, Hilbert spaces, the Reisz Representation Theorem, orthonormal sets, orthogonal complements, bounded operators on Hilbert space up to the spectral theorem for compact, self-adjoint operators.

Elementary probability: Axioms, conditional probability, Baye's theorem, Permutations and combinations, Random numbers, distributions- discrete, continuous, Poisson, Gaussian. Statistics: Experiments, samples, populations; Averages, variance, standard deviation, moment, covariance and correlation; Maximum-Likelihood method- ML estimator, Bayesian interpretation, large N behavior; Least Squares Method, Hypothesis testing: Student's t-Test, goodness of fit

Reference books:

- Mathematical methods for Physics and engineering -by Riley, Hobson and Bence
- Elementary Linear Algebra (9th Edition) -by Howard Anton, Chris Rorres
- Introduction to real analysis -by Bartle.

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Course Code	**:** CNN 104	**Compulsory Course**	
Name of the course	**:** Essential Biology		
Credits	**:** 4	**Total Lectures**	**:** 60

Molecules of Life (15 L)

Water (Structure, properties and physiological importance; pH and biological buffer systems); Carbohydrates (Classification, structures, properties and functions); Lipids, phospholipids, biological significance of lipids); Amino acids (Classification based on polarity, nutritional and metabolic requirement, structure and properties); Proteins (function and properties, peptide bond, protein structure-primary, secondary, tertiary and quaternary, forces stabilizing the structure of proteins and macromolecules); Enzymes (class and functions, mechanism of action of enzymes, regulation of enzymes); Nucleic acids (structure of purines, pyrimidines, nucleoside, nucleotide, DNA and RNA, types of nucleic acids); central dogma of molecular biology

Biophysical techniques (15L)

Observation of cells – microscopy; isolation and breaking of cells; preparation of biological samples for analysis; separation of cells – centrifugation; isolation, purification and characterization of bio-molecules; separation and purification techniques – chromatography and electrophoresis; spectrophotometry; isotope trace and autoradiography; tools to study the conformation of macromolecules and their interactions

Cell Biology (15L)

Chemical nature of cells; structure of cells (Prokaryotic – bacteria and archaebacteria, eukaryotic – fungal, plant and animal viruses – structure and classification); Ultrastructure of cell membrane and call wall – chemical composition; models and their functions; Ultrastructure od cytoplasm and cytoplasmic organelles (golgi bodies, endoplasmic reticulum, mitochondria, ribosomes, lysosomes, perioxisomes, nucleus, cytoskeleteon, cilia, flagella and chloroplast); Transport of substances through the cell membrane – osmosis, diffusion, types of transport – active transport (Sodium – potassium pump) and Passive transport; Membrane potential – measuring membrane potential, Action potential

Cell Signalling, Immune system (15L)

Cell communication – signalling molecules and their receptors; Functions and types of cell surface receptors; signal transduction pathways; Signal transduction and cytoskeleton; Regulation of programmed cell death; Immunity – innate and adaptive immunity; Introduction to antigen presenting cells, complement system and tumour immunology; Life cycle of HIV; Monoclonal antibodies synthesis and application

Reference Books:

- David L. Nelson and Micheal M. Cox; Lehninger Principles of Biochemistry; 5th Edition (2008) and upwards; W.H. Freeman
- John Kuriyan, BoyanaKonforti, David Wemmer; The Molecules of Life Physical and Chemical Principles; (2012); Garland Science
- Roland Glaser; Biophysics: An introduction; 2nd Edition (2012); Springer
- Jenni Punt, Sharon Stranford,Paticia Jones, Judith A Owen; Kuby Immunology; 6th Edition and upwards (2006); W.H.Freeman

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Course Code	**:** CNN 111	**Practical Course**
Name of the course	**:** Physics Lab	
Credits	**:** 2	**Total Practical's : 12**

1. Light as Wave: Wavelength determination using diffraction experiments
2. Contact Angle Measurements: Different solvents on different solids.
3. Study of Photoelectric effect, inverse square law and LDR.
4. UV-Vis-NIR Spectroscopy to extract Band gap of a Semiconductor.
5. XRD Analysis of powder samples.
6. Parallel plate capacitor & Dielectric constant measurement experiment.
7. Understanding atomic model using hydrogen spectra.
8. P – N Junction &Zener Diode Characteristics (Forward & Reverse biased)
9. Input & Output Transistor Characteristics (Common Emitter, Base & Collector).

10. FET Characteristics.
11. MOSFET Characteristics.
12. Magnetic Susceptibility Measurements using Magnetic Hysteresis loop tracer.
13. Hall Effect, mobility and carrier concentration measurements for semiconductor.
14. Two probe - Four probe conductivity measurement techniques.
15. Hands on experience on Thermal Evaporation setup
16. Demonstration on DC Sputtering set up
17. Demonstration on Pulsed Laser Deposition set up
18. Low temperature Resistivity measurement of a thin film.
19. Film thickness measurement using optical profilometer.
20. Leak Detection in a vacuum system using Helium Leak Detector.

Reference Books

1. Fundamentals of Molecular Spectroscopy by C. N. Banwell, McGraw-Hill
2. Electronic Principles by A. Malvino and D. Bates
3. Handbook of Thin Film Deposition, Hartmut Frey, Hamid. R. Khan Editors.

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Course Code	**:** CNN 112	**Practical Course**
Name of the course	**:** Chemistry Lab	
Credits	**:** 2	**Total Practical's: 12**

1. Titration of a mixture of trichloroacetic acid, monochloroacetic acid and acetic acid with sodium hydroxide conductometrically.
2. Verification of Ostwald's dilution law and determination of the dissociation constant of a weak monobasic acid conductometrically.
3. Study of the effect of substituent on dissociation constant of acetic acid conductometrically.
4. Determination of concentrations and amounts of iodide, bromide and chloride in mixture by potentiometric titration with silver nitrate.
5. Devarda's Alloy: Cu by ETDA method, Al by Gravimetric using oxine.
6. Cu-Ni Alloy: Cu by iodometric method; Ni gravimetrically by DMG method.
7. Determination of the stability constant of the complex formed between iron (III) and 5-sulphosalicyclic acid at pH=2 and pH=3 by colorimetric method.
8. Determination of solubility product of silver chloride potentiometrically using a concentration cell.
9. Solder Alloy: Sn gravimetrically by oxide method; Pd by EDTA method.
10. Lime Stone Ore: Loss on ignition; Ga by ETDA method.
11. Hematite Ore: Acid insoluble residue; Fe by redox titration.
12. Determination of the formula of silver-ammonia complex by potentiometric method.
13. Determination of pK values of phosphoric acid by potentiometric titration with sodium hydroxide using glass electrode.
14. Determination of acidic and basic dissociation constants of an amino acid and hence the isoelectric point of the acid.

Reference Books

- A. W. Admson, Physical Chemistry of Surfaces, Wiley-Interscience (1990)
- E. Matijevic, Surface and colloid science, Wiley Inter science (1969)
- P. W. Atkinson, Physical Chemistry: ELBS with Oxford University Press
- I. N. Levine, Physical Chemistry: Mc-Grow Hill

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Course Code	**:** CNN 113	**Practical Course**
Name of the course	**:** Biology Lab	
Credits	**:** 2	**Total Practical's: 12**

1. Introduction to Nanobiology Laboratory (Instrumentation, Good Laboratory Practices, Demonstration of bio-safety measures, Autoclaving and sterilization of culture media)
2. Handling biological samples and BSL Facilities (Plant origin, Animal Origin, Microbiological; Lab visit to BSL2 facility; video demonstration of BSL3 and BSL4)
3. Handling and culturing of microorganisms: Plate pouring, streaking and inoculation (microflora of food samples: mango/apple/grape/banana/fruit juices)
4. Microbial cell counting by serial dilution technique
5. Antimicrobial testing of microorganisms technique
6. Identifying human blood cells, Separation of serum and plasma from blood sample
7. Identification of human's A, B, O blood group system; Determination of Rh Factor of Blood
8. Numericals to understand IC50 values
9. Synthesis of Nanoparticles from plant materials
10. Synthesis of nanoparticles from microbiological sources
11. Action of nanoparticles on biofilms
12. Affinity purification of immunoglobulins & quantification
13. Demonstration of Imaging techniques: SEM/TEM/Bio-AFM (Natural Sample sources)
14. Biocompatibility of nanoparticles – Hemolytic assay
15. Bioconjugation of nanoparticles with proteins/antibodies/DNA
16. Protein quantification by BCA/Fluorescence spectroscopy/ELISA
17. Mining of biological databases: DNA/Protein search

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Course Code	**:** CNN 114	**Practical Course**
Name of the course	**:** Mathematical Lab	
Credits	**:** 2	**Total Practical's : 12**

1. Analysis and Linear Algebra Convergence: Determine whether the given series (many) is absolutely convergent, convergent or oscillatory.
2. Taylor and McLaurin series: Expansion of various functions using Taylor series McLaurin series.
3. Linear Algebra: Vector Spaces; Determinants: Evaluate given determinants and solve a set of simultaneous linear equations.

4. Eigenvalues and eigenvectors: Find eigenvalues and a set of eigenvectors for a given matrix (or matrices) and determine whether the eigenvectors are mutually orthogonal.
5. Trigonometry, applications of Fourier series and transforms

Trigonometry and wavefunction: Plotting and analyzing various waveforms; Fourier Series: various function modeling tutorial. Fourier transforms: analysis of data from various examples in experiments.

3. Probability and Statistics

Tutorial on various distributions; Physical statistics: Data analysis- Least Squares; Bio related statistics: Student's t-Test analysis.

Reference Books:

- Elementary Linear Algebra (9th Edition) -by Howard Anton, Chris Rorres
- Introduction to real analysis -by Bartle.

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Semester II

Course Code	**:** CNN 201	**Compulsory Course**
Name of the course	**:** Solid State Physics and Thermodynamics	
Credits	**:** 4	**Total Lectures:** 60

Crystal Structure, Diffraction and reciprocal lattice: (**15L)**

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, Direct Imaging of Atomic Structure, Non-ideal Crystal Structures, Crystal Structure Data.), Bragg Law, Fourier Analysis, Reciprocal lattice vectors, Diffraction Conditions, Laue Equations, Brillouin Zones, Structure factor of BCC and FCC Lattice, Atomic Form factor.

Lattice Vibrations:(15 L)

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 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,

Magnetic ordering in crystals:(15 L)

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, explaination of Hysterisis, Antiferromagnetism, Ferrimagnetism. Superconductivity :A Experimental survey of superconductivity, Joule heating, Critical currents, Effect of magnetic field and phenomenon of Meissner effect, Thermal properties: entropy-specific heat-thermal conductivity, Isotope Effect, Penetration depth, Type I and Type II superconductors, BCS theory of superconductivity, Coherence length, Josephson tunneling, SQUID, Different superconducting materials and its transition temperatures,

Thermodynamics (15 L)

State functions and exact differentials. Internal Energy, Enthalpy, Heat Capacity, Joule-Thomson coefficient. Clausius inequality, Entropy, Maximum Work, Thermodynamic equation of state, Maxwell relations, Helmholtz and Gibbs free energy, Temperature dependence of thermodynamic functions. Partial molar quantities, Chemical potential, Chemical potentials for ideal gases , gas mixtures and homogeneous solutions in multi component systems. Free energy, entropy and enthalpy of mixing for ideal gas mixtures and solutions, Fugacity and its relation to pressure, Equilibrium constant and its dependence on temperature and pressure. Vapor pressure – composition diagrams, Activity and activity coefficients, Excess functions, Gibbs-Duhem equation. Third law of thermodynamics, temperature dependence of entropy Phase rule and Phase Equilibria. Phase diagrams and their classification. Lambda transitions. Phase diagrams for partially miscible liquids for two components. Three Component Systems (Graphical representations of systems of three liquids, one pair of partially miscible liquid, bimodal curves, plait point, influence of temperature.)

Experimental techniques for determination of thermodynamic quantities. Applications of Thermodynamics to Fractional Distillation, Zone Refining, Fuel Cells and Corrosion Processes. Thermodynamics of surfaces, Gibbs adsorption isotherm. Debye-Hückel theory, ionic atmosphere, activity coefficients of electrolyte solutions: Debye-Hückel limiting law, extension to higher concentrations. Electrolytic conductance and ion-ion interactions, Debye-Hückel-Onsager equation, Debye-Falkenhagen effect, Wien effect.

Reference Books:

4. Introduction to Solid State Physics by Charles Kittle; Wiley-India.
5. Solid State Physics by Neil W. Ashcroft, N. David Mermin; Brooks/Cole Cengage Learning.
6. Solid State Physics by S.O. Pillai; New Age international Publishers.
7. Elementary Solid State Physics by M.A.Omar, Pearson Education.
8. Solid State Physics by Allen J.Dekker, MacMillan India Ltd.
9. Solid State Physics by M.A. Wahab; Narosa Publications
10. Solid State Physics by Philip Hofmann; Wiley-VCH
11. Introductory Solid State Physics by H.P. Myers

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Course Code	**:** CNN 202	**Compulsory Course**	
Name of the course	**:** Fundamentals of nanomaterials		
Credits	**:** 4	**Total Lectures**	**:** 60L

Introduction to miniaturization. (15 L)

Background, historical development of nanomaterials, units, Scaling laws: (in mechanics, electricity, electromagnetism, optics, heat transfer, fluids), organization of matter- atoms, molecules, clusters and supramolecules. Need based introduction to quantum effects.

Structure and Bonding: Chemical bonds (types and strength), Intermolecular forces, Molecular and crystalline structures- Bulk to surface transition, density of states, bandgap and dimensionality of nanomaterials, surface reconstruction, self-assembly.

Synthesis of Nanomaterials. (15 L)

Physical Methods: Mechanical, evaporation, chemical vapour deposition, ion beam techniques, molecular beam epitaxy, laser deposition.

Chemical methods: Colloids and colloids in solution, Langmuir-Blodgett (L-B) method, micro emulsion, sol gel methods, electrochemical methods etc.; uniformity of nanomaterials (size, properties distribution and yield)

Bio inspired methods: Microorganisms, plant based, using proteins and DNS templates, etc.

Examples of special nanomaterials. (15 L)

2D materials, Carbon based materials, aerogels, zeolites, self-assembled nanomaterials, core shell particles, Nano Metals, Nano Ceramics, Nano Composites, other current interest nano structured / nano materials.

Scope of nanomaterials and their applications (15 L)

Mechanical, magnetic, electrical, optical, biocompatibility, toxicity, chemical, emergent quantum properties.

Nano-electronics, Nano-optics, Nano magnetic-, chemical- and bio-sensing, energy applications, textiles, cosmetics, biotechnology, medical, construction, defence, and other contemporary applications.

Reference books:

1. Springer Handbook of Nanomaterials, -by Robert Vajtai
2. Nanotechnology: principles and practices, -by S. K. Kulkarni
3. Nanotechnology the whole story, -by B. Rogers, J Adams and S. Pennathur

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Course Code	**:** CNN 203	**Compulsory Course**
Name of the course	**:**Atoms, Molecules and Spectra's	
Credits	**:** 4	**Total Lectures :** 60

Quantum Mechanics (15 L)

The physical basis of quantum mechanics (experimental background, old quantum theory, the Heisenberg Uncertainty Principle, wave packets in space and time), the Schrödinger wave equation (development of the wave equation, interpretation of the wave function, energy eigenfunction, 1-D square wave potential), operators of Quantum Mechanics (state vectors, observables and operators, ket-space, bra-space and inner product, Hermitian), Representations in different bases Time-evolution of a quantum system (Schrödinger, Heisenberg and Interaction pictures), 1-D problems in quantum mechanics (wells and barriers, Harmonic oscillator, etc.),Application of variational principle, Hamilton's principle, Hamilton's equations of motion.

Atoms and Molecules (15L)

Multielectron atoms (identical Particles, The Exclusion Principle, Exchange Forces and the Helium Atom, Ground States of Multielectron Atoms and the Periodic Table, X-Ray Line Spectra, Alkali Atoms, Atoms with Several Optically Active Electrons, LS Coupling, energy Levels of the Carbon Atom, The Zeeman Effect), Molecules (Ionic Bonds, Covalent Bonds, Molecular Spectra, Rotational Spectra, Vibration-Rotation Spectra , Electronic Spectra

Metals semiconductors and insulators: (15 L)

Band Gap, Electrical Conduction in Metals, The Quantum Free-Electron Model, The Motion of Electrons in a Periodic Lattice, Effective Mass, Electron-Positron Annihilation in Solids, Semiconductors, Semiconductor Devices.

Dielectric Properties of Materials: (15 L)

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.

Reference Books:

- Introduction to quantum mechanics by D. Griffiths, Prentice Hall
- Principles of Quantum Mechanics by R. Shanka, Plenum Press
- Quantum Mechanics by L. I. Schiff, McGrew Hill
- Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles by R. Eisberg, John Wiley and Sons

- Fundamentals of Molecular Spectroscopy by W. S. Struve, John Wiley and Sons
- Fundamentals of Molecular Spectroscopy by C. N. Banwell, McGraw-Hill.
- Quantum Chemistry by R. K. Prasad
- Quantum Chemistry by I. N. Levine: Pearson Prentice Hall
- Physical Chemistry: A molecular approach by McQuarine and Simon: Viva Books Pvt. Ltd.
- Fundamentals of quantum chemistry by R. Anantharaman:Macmillan India Limited

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Course Code	**:** CNN 204	**Compulsory Course**
Name of the course	**:** Experimental Methods	
Credits	**:** 4	**Total Lectures:** 60

Vacuum Pumps and Gauges (15L)

Fundamentals of Vacuum (Vacuum, Types of Vacuum, Free gas, volume, pressure, pressure measurements, Gas Laws, Gas flows, Mean free path, Conductance, Throughput), Pumping Techniques (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 Gauges (Bourdon gauge, Capacitance manometer, Thermocouple Gauge, Pirani Gauge, Penning/Cold Cathode Gauge, Hot Cathode Gauge, McLeod Gauge, Residual Gas Analyser), Vacuum Materials & Hardware (Flanges, Valves, Feedthroughs). Helium Leak Detection**.**

Applications of Vacuum Techniques (15 L)

Physical Vapor Deposition (Thermal Evaporation, Cathodicvapour arc deposition, Electron-beam physical vapour deposition, Pulsed Laser Deposition, Molecular Beam Epitaxy, Sputtering (DC, RF & Magnetron sputtering), Ion implantation, Ion etching), Chemical & Electrochemical Methods: Chemical Vapour deposition.

Methods of material characterization Techniques (15 L)

Principles of X-ray diffraction – Bragg´s law, powder XRD, Bragg-Brentano geometry, thin film XRD in this geometry, phase identification from XRD peaks, Determination of lattice parameters, crystalline size using Debye-Scherer equation. X-ray reflectivity – Basic principles of specular reflectivity, determination of thin film thickness, roughness (surface and interfacial) and density.

Electrical Properties: Two Probe and Four Probe Resistivity technique, Impedance Analysis using LCR Meter. Magnetic Properties:Vibrating Sample Magnetometer (VSM),Kerr Effect Magnetometer (MOKE).

Microscopic and spectroscopic characterization techniques (15 L)

Microscopy: Scanning electron microscopy (SEM), Atomic Force Microscopy (AFM), Scanning Tunnelling Microscopy (STM), Transmission electron Microscopy (TEM).

Spectroscopy:UV-Vis – NIR Spectroscopy, Secondary Ion Mass Spectroscopy (SIMS), Rutherford Backscattered Spectrometry (RBS), X - Ray Photoelectron spectroscopy (XPS); Fourier Transformed Infrared Spectroscopy (FTIR), Raman Spectroscopy, Photoluminescence (PL).

Reference Books:

1) Handbook of Vacuum Science & Technology by D. M. Hoffmann, B. Singh, J. H. Thomas, Academic Press.
2) Basic Vacuum Practice, Third Edition, Varian Publications.
3) An Introduction to Electron Microscopy & Instrumentation, Imaging & Preparation, By Andres Kaech

4) Handbook of Thin film Deposition by Gary. E. Mcguire, Series Editor, Stephen. M. Rossnagel, Series Editor, Rointan. F. Bunshah Founding Editor.
5) Handbook of Thin Film Deposition, Hartmut Frey, Hamid. R. Khan Editors.
6) Principles of Instrumental Analysis, D. A. Skoog, F. J. Holter and S. R. Crouch, Thomson Brooks/Cole, 2007.
7) Instrumental Methods of Analysis,Hobart H. Willard, John A. Dean, Lynne L. Merritt D. Van Nostrand Company.
8) Elements of X-ray diffraction, B. D. Cullity, Creative Media Partners, LLC.

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Course Code **:** CNN 205 **Optional Course**
Name of the course **:**Nanobiotechnology: Concepts, Applications & Tools (Nano-CAT)
Credits **:**4 **Total Lectures:** 60

Concepts of Nanobiotechnology&Nanobiomaterials (15 L)

Basics of Biolology, Introduction of Bionanoscience and Bionanomaterials, Biomacromolecules, Bionanomachines, DNA Nanotechnology, Peptide Nanotechnology Cellular Engineering, Ethical issues, Tools and techniques in nanobiotechnology.

Nanobiomaterials: Metallic, Metal oxide based, Ceramic, semiconducting, organic-inorganic hybrid, silica based, polymeric nanocomposites. Lipoproteins, peptide, Polypeptide, Protein and Virus based biologically directed/ self-assembled nanobiomaterials- DNA origami, Peptoid structures, Nanomaterials and biosystems interaction.

Nano-Biomedicine &Nanotheranostics (15 L)

Nanobiomolecules crossing blood brain barrier, bioconjugation and biocompatibility.

Tissue engineering: Biomemetics design, Nanobiomechanics of living cells, Multi-functional nanozymes, Polymeric scaffolds, Nanoengineered hydrogels, cell repair machines, Fundamentals of Drug and gene delivery, gene alteration, cell interactions, Stem cell treatment, Biopharmaceuticals, medical implications.

Biochips, Micro arrays, BioMEMs, Molecular Imaging, Cancer therapy using nanomedicine- Use of nanotubes, quantum dots, polymeric conjugates, Dendritic nanostructures, Fe/Au Nanoshell for tumor targeted imaging, delivery and therapy, Use of multifunctional nanoparticles in chemotherapy, Molecular nanosubmarines, Photoablation and hyperthermia,Nanoencapsulation technologies.

Case studies: Commercialisednanobiotechnology related products (15 L)

Verisens in Prostate specific antigen diagnosis, Ferride as MRI contrast agent for liver lesions, Biosilicon in drug delivery, PuraMatrix in tissue repair and cell therapies, GeniaBeads for wound healing, Apligraf as dermal matrix for organogenesis, Healos-Bone graft substitute in spinal fusions, Integra- Scaffold for dermal regeneration, Gelrite as ophthalmic vehicle, Abbott and Roche point of care products, Biocon for pharmaceutical products, Pegylated streptokinase as clot buster.

Bioinformatics concepts, Intellectual property & business development (15 L)

Biological databases, search, Literature mining, sequence alignment, phylogenetic tree construction, primer designing and gene prediction, Protein modeling.

Intellectual property basics, publications, impact factor, citation index, national and international patents, copyright laws, trade secrets, prior-art-search, confidentiality non disclosure agreements. Development of business model, joint ventures, science innovation parks, incubation start up schemes, product & technology development, proof of concept, prototype, scaling up of a product.

Reference Books

1. Nanobiotechnology: Concepts, Applications and Perspectives by Mirkin Chad, Wiley
2. Nanobiotechnology-Concepts and Applications in Health, Agriculture, and Environment by R. Tomar, Apple Academic Press
3. Nanobiotechnology in Food: Concepts, Applications and Perspectives by J.M. Hoda, Springer
4. Nanomaterials Handbook by Y. Gogotsi, CRS Press, Taylor and Francis Group
5. WIPO Intellectual Property Handbook: Policy, Law and Use.

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Course Code	**:** CNN 206	**Optional Course**
Name of the course	**:** Nanotechnology food and agriculture	
Credits	**:** 4	**Total Lectures :** 60

Agricultural Nanotechnology: (15 L)

Conventional Farming: Issues and Limitations, Intensive Conventional Farming AffectsEnvironment, Current Agricultural Production Systems, Nanotools -Nanoprocesses, andNanomaterialsProduction of Bionanomaterials from Agricultural Wastes**:**Cellulose and Nanocellulose from Citrus and Orange Wastes, Synthesis of Graphene Oxidefrom Agrowastes, Production of Amorphous Silica Nanoparticles from Agrowastes, CarbonNanomaterials from Agrowastes,Nanoengineering Superabsorbent Materials in Agriculture: Introduction,Formation and Structure of Cross-Linked Polyacrylates, Formation and Structure of Cross-Linked Polyacrylates; Statistical Models, Mechanisms of Swelling in SuperabsorbentPolymers, Mechanisms of Swelling in Superabsorbent Polymers; Hydration, Hydrogen Bonds,Properties of Superabsorbent Polymers, Absorption of Aqueous Solution, Moisture AbsorptionSuperabsorbent Polymers Application in Agriculture, Superabsorbent/Clay Nanocomposites

Nanotechnology in plant protection (15 L)

Nanotechnology and Their Applications in Insect's Pest Control; Formulations of Nanoinsecticides-Nanoemulsions, Components, Preparation, Types and Methods,Nanoparticle-Based Plant Disease Management; Interactions between NPs, Pathogens, and Plants, Plant Disease Diagnosis Using different NPs, Nanotechnology in Microbial Plant Pathogen and insect Management, Nanoantimicrobials Mechanism of Action, Chitosan-Based Nanostructures in Plant Protection.; Synthesis and characterisation of NPs and Nanocomposite Copper Nanostructures Applications in Plant Protection, Nanosensors for Monitoring Soil Conditions and Environmental Stresses;Carbon Nanotube, Nanoaptamers, Smart Dust Technology, Nanocapsules for Efficient Delivery of Pesticides, Fertilizers and Agrochemicals; Targeted Delivery of Agrochemicals Using Nanotechnology, Nano-based Pesticides in Agriculture, Nano-based Fertilizer Efficiency, Improving Plant Traits against Environmental Stresses Using Nanotechnology, Nanotechnology and Its Applications in Water Conservation

Nanoparticles in food production and diagnostics (15 L)

Food and New Ways of Food Production - Efficient Fractionation of Crops Efficient Product Structuring -Optimizing Nutritional Values - Applications of Nanotechnology in Foods : Sensing, Packaging, Encapsulation, Engineering Food Ingredients to Improve Bioavailability - Nanocrystalline Food Ingredients - Nanoemulsions - Nano-Engineered Protein Fibrils as Ingredient Building Blocks Preparation of Food Matrices - Concerns about Using Nanotechnology in food production.Diagnostics Enzyme Biosensors and Diagnostics - DNA- Based Biosensors and Diagnostics Radiofrequency Identification- Integrated Nanosensor Networks: Detection and Response- Lateral Flow

(Immuno)assay - Nucleic Acid Lateral Flow (Immuno)assay - Flow-Through (Immuno)assays - Antibody Microarrays Surface Plasmon Resonance Spectroscopy.

Nanotechnology in food packaging (15 L)

Crop improvement - Reasons to Package Food Products - Physical Properties of Packaging Materials - Strength - Barrier Properties Light Absorption – Structuring of Interior Surfaces - Antimicrobial Functionality - Visual Indicators – Quality Assessment - Food Safety Indication - Product Properties - Information and Communication Technology - Sensors -Radiofrequency Identification Technology- Risks - Consumer and Societal Acceptance.

Reference Books:

1) Nanobiotechnology Applications in Plant Protection by Kamel A. Abd-Elsalam and Ram Prasad, Volume 2, Springer, 2018.
2) Nanotechnology an Agricultural Paradigm by Ram Prasad, Manoj Kumar, Vivek Kumar Springer, 2017.
3) Nanoscience in Food and Agriculture by ShivenduRanjan, Volume 1, Springer, 2016.
4) Nanotechnology and Plant Sciences by Manzer H. Siddiqui, Springer, 2015.
5) Nanoparticle Assemblies and Superstructures by Nicholas A. Kotov, CRC, 2006.
6) Nanotechnology in agriculture and food production by Jennifer Kuzma and Peter VerHage, Woodrow Wilson International, 2006.
7) Bionanotechnology by David S Goodsell, John Wiley & Sons, 2004.
8) Nanobiomaterials Handbook by BalajiSitharaman, Taylor & Francis Group, 2011.

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Course Code	**:** CNN 207	**Optional Course**
Name of the course	**:**Medical nanotechnology	
Credits	**:** 4	**Total Lectures :** 60

Introduction (15 L)

Concept of a living cell; Unicellular and multicellular organisms; Types of tissues; Microorganisms (Structure, types and clinical significance); Viruses (structure, types and clinical significance); Relation of Nanobiotechnology to Nanomedicine; Landmarks in the Evolution of Nanomedicine (Nano Shells, Nano pores, Tectodendrimers); Intrinsic biocompatibility of nanoparticle in cellular system - degradable and non-degradable polymers, Cytotoxicity mechanisms and their potential use in therapy (Antibiotics, photodynamic therapy, magnetic hyperthermia); Nanoparticle toxicity

Nanocapsules (15 L)

Preparation, Characterization and Therapeutic Applications; Nanocapsules obtained by interfacial polymerization; Oil-containing nano capsules; Nanocapsules containing anacqueous core, Nanocapsules obtained from preformed polymers; Characterization; Drug Release; Oral route; Parenteral route; Ocular route delivery

Magnetic Nanoparticles (15 L)

Definitions; Properties; Preparation, Characterization, Applications in MRI imaging (contrast agents); Iron oxide based magnetic nanoparticles; Cobalt based magnetic nanoparticles; Iron based magnetic particles; Encapsulated magnetic nanoparticles; Biocompatibility issues of magnetic nanoparticles; Magnetic hyperthermia; Magnetic chemotherapy; Other magnetic treatment approaches; Magnetic gene transfer

Nanoparticles in Drug delivery (15 L)

Nanoparticle-Based Drug Delivery (targeted- site specific, opsonization; and non-targeted); Gold Nanoparticles as Drug Carriers; Calcium Phosphate Nanoparticles; Cyclodextrin Nanoparticles for Drug Delivery; Dendrimers for Drug Delivery; Fullerene Conjugate for Intracellular Delivery of Peptides Polymer Nanoparticles; Ceramic Nanoparticles; Encapsulating Water-Insoluble Drugs in Nanoparticles; Self-Assembling Nanoparticles for Intracellular Drug Delivery Particle; Replication in Non-wetting Templates Flash Nano Precipitation; Nanoparticle Combinations for Drug Delivery

Reference Books:

1. Yoseph Bar Cohen, ―Biomimetics: Biologically Inspired Technologies‖, CRC Press, Boca Raton,
2. Reza Arshady and Kenji Kono, ―Smart Nanoparticles in Nanomedicine‖, MML series volume 8, Knetus Books, London, 2006
3. Ramakrishna S, MuruganRamalingam, and Kumar T. S. S., ―Biomaterials: A Nano Approach‖, CRCPress, London, 2010.
4. BikramjitBasu and Ashok Kumar K., ―Advanced Biomaterials: Processing and Applications‖, John Wiley, New Jersey, 2009.
5. Hari Singh Nalwa, ―Handbook of Nanostructured Biomaterials and Their Applications In Nanobiotechnology‖ ,American Scientific Publishers,2005.
6. Cato T. Laurencin, Temenoff J. S. and Mikos A. G., ―Biomaterials: The Intersection of Biology and Materials Science‖, Pearson, New Delhi, 2009.
7. Astrid Sigel, Helmut Sigel and Roland K. O. Sigel, ―Biomineralization: From Nature to Application‖, John Wiley, 2010.
8. Stephen Mann, ―Biomineralization: Principles and Concepts in Bioinorganic Materials Chemistry‖, Oxford Univ. Press, 2001.
9. Robert A and Freitas Jr, ―Nanomedicine Volume IIA: Biocompatibility‖, S Karger Ag, Switzerland, 2003.
10. Alf Lamprecht, ―Nanotherapeutics Drug Delivery Concepts in Nanosience‖, Pan Stanford Publishing, Singapore, 2009

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Course Code **:** CNN 208 **Optional Course**
Name of the course **:**Nanotechnology- Environmental, Ethical and Economic Impacts
Credits **:** 4 **Total Lectures :** 60

Introduction (15 L)

Identification of Specific Risks – Challenges- Human health hazard – Risk reduction – Standards, Safety – Transportation of nanoparticles, Emergency responders, Risk assessment –Environmental Impact, Predicting hazard – Materials, Characterization – Environmental and policy making – Ecotoxicity measurement; Environmental treatment using nanotechnology – Gas sensors, Nanomembrane process nanosorbants – Mesoporous materials – Ground water remediation – Air purifier – Nano photocatalysis - Pt nanoparticles for sulphur removal – Ge nano particles for lead removal.

Nanotoxicology (15 L)

Major routes of administration; Types of tissues involved; Inhalation, deposition and Pulmonary clearance of insoluble solids – Bio persistence of Inhaled solid material – Systemic; Translocation of inhaled Particulates – Pulmonary effects of CNTs – Inflammatory ; response–

In-vivo interactions of pulmonary inflammation with oxidative stress – Interactions of CNTs with Macrophages; Nanoparticle exposure and systematic cardiovascular effects – experimental data – respiratory particulate matter exposure and cardiovascular toxicity – Toxicity of polymer nanoparticles – Drug carriers – Particle exposure in indoor and air environment – Measurement of indoor particulate matter.

Ethics (15 L)

Nanoparticle Hypothesis – Need for regulations, health protection and environmental security – Laboratory practices –Definition- Benefits – Potential risks – Assessment of exposure – Bioethics and legal aspects of potential health and environmental risks. Ethical and societal implications - the public interface of science technology and human values - origins of the precautionary principle - the citizen as moral agent - the principle of social justice - utilitarian priorities; The role of fore-sighting

Economic Impact (15 L)

Managing the Nanotechnology Revolution: Consider the Malcolm Baldrige National Quality Criteria - The Emerging Nano Economy: Key Drivers, Challenges, and Opportunities -Transcending Moore's Law with Molecular Electronics and Nanotechnology -Semiconductor Scaling as a Model for Nanotechnology Commercialization - Sustaining the Impact of Nanotechnology on Productivity, Sustainability, and Equity; Management of Innovation for Convergent Technologies -The "Integration/Penetration Model:" - The Use of Analogies for Interdisciplinary Research in the Convergence of Nano-, Bio-, and Information Technology - Converging Technologies: Innovation, Legal Risks, and Society .Governance- Problems of Governance of Nanotechnology -Institutional Impacts of Government Science Initiatives - Nanotechnology for National Security

Reference Book :

1. Nancy A, ―Monteiro Riviere Lang Tran‖, Nanotoxicology, CRC Press, 2014
2. Deb Bennett Woods, ―Nanotechnology: Ethics and Society‖, CRC Press, Taylor and Francis Group, 2008.
3. Lynn Goldman and Christine Coussens, ―Implications of Nanotechnology for environmental Health Research, National Academic Press, Washington,2007.
4. Patrick Lin, Fritz Allhoff, ―Nano-ethics: The Ethical and Social Implications of Nanotechnology‖, John Wiley & Sons, New Jersey, 2007.
5. Grassian V.H, "Nanoscience and Nanotechnology – Environmental and health impacts", John Wiley & Sons, 2008
6. Sellers.K, Mackay.C, Bergeson.L.L, Clough S.R, Nanotechnology and Environment, CRC Press, 2009.
7. Ram.M, Andreescu.S.E, Hanming.D, "Nanotechnology for Environmental Decontamination", 2011, McGraw Hill
8. Wiesner M and Bottero J.Y, "Environmental Nanotechnology", McGraw-Hill, 2007.
9. Geoffrey Hunt and Michael D. Mehta ―Nanotechnology: Risk, Ethics and Law‖, Earthscan/James & James publication (2006)
10. Jurgen Schulte ―Nanotechnology: Global Strategies, Industry Trends and Applications‖, John Wiley & Sons Ltd (2005)\
11. Mark. R. Weisner and Jean-Yves Bottero ―Environmental Nanotechnology applications and impact of nanomaterial‖, The McGraw-Hill Companies (2007).
12. Mihail C. Roco and William Sims Bainbridge ―Nanotechnology: Societal Implications II-Individual Perspectives‖, Springer (2007)

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Course Code : CNN 211 **Practical Course**

Name of the course :**Synthesis and Characterization of Nanomaterials I (Chemical and Biological methods)**

Credits : 2 **Total Lectures Credits** :

Chemical methods

1. Synthesis of Bimetallic nanoparticles by wet chemical method and confirm the formation by UV-Vis analysis.
2. Synthesis of Copper/ Silver/ Gold nanoparticles by simple chemical reduction method and confirm the synthesis of size dependent nanomaterial by surface plasmon resonance analysis.
3. Synthesis of Iron oxide nanoparticles by wet chemical method and confirm the synthesis by band gap analysis.
4. Synthesis of Nickel ferrite nanoparticles by co-precipitation method and characterize the product by FTIR analysis
5. Synthesis of CdSe nanoparticles by simple wet chemical method and demonstrate the size vatiation.
6. Synthesis of ZnO quantum dots by simple solvothermal synthesis and confirm the size dependent variation in band gap.
7. Electroplating of Cu on conducting substrate and determine its reduction potential.
8. Chronoamperometry study for the deposition of semiconductor thin film.
9. Electrophoretic deposition of metal nanoparticle and determine the deposition potential.

Biology Methods

10. Synthesis of Nanoparticles from plant materials
11. Synthesis of nanoparticles from microbiological sources
12. Affinity purification of immunoglobulins & quantification
13. Demonstration of Imaging techniques: SEM/TEM/Bio-AFM (Natural Sample sources)
14. Bioconjugation of nanoparticles with proteins/antibodies/DNA
15. Protein quantification by BCA/Fluorescence spectroscopy/ELISA
16. Mining of biological databases: DNA/Protein search

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Reference Books

- Fundamentals of Molecular Spectroscopy by C. N. Banwell, McGraw-Hill
- Handbook of Thin Film Deposition, Hartmut Frey, Hamid. R. Khan Editors.
- Elements of X-ray diffraction, B. D. Cullity, Creative Media Partners, LLC.

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Course Code	**:** CNN 214	**Practical Course**
Name of the course	**:Synthesis and Characterization of Nanomaterials II**	
Credits	**:** 2	**Total practical's:**8

1. To study Hydrogen evolution reaction, Oxygen evolution reaction, Oxygen reduction reaction, by rotating disc analysis.
2. To perform Electrochemical Impedance spectroscopy analysis heterojunctions.
3. To study cyclic voltammetry of semiconductor quantum dots.
4. To identify and analyse the nanomaterial by Raman spectroscopy.
5. To identify an analyse the given nanomaterial by FTIR spectroscopy.
6. To analyse and confirm the crystal structure of given sample by X-ray diffraction technique.
7. To perform the time resolved photoluminescence study on nanoparticles/ quantum dots.
8. To carryout Photoluminescence study of the given nanoparticles.

Reference Books

1. Instrumental Methods of Analysis,Hobart H. Willard, John A. Dean, Lynne L. Merritt D. Van Nostrand Company.
2. Fundamentals of Molecular Spectroscopy by C. N. Banwell, McGraw-Hill

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