Annexure-I

DEPARTMENT OF NANOTECHNOLOGY
UNIVERSITY OF KASHMIR

NAAC Accredited Grade A+

SRINAGAR-190006

Curriculum
for
Bachelor of Science (B.Sc.) Honors Program
In
Nanotechnology
2023 Onwards
(Semesters I-IV)

Approved in the Board of Undergraduate Studies Meeting
Department of Nanotechnology University of Kashmir

on

June 09, 2023 & October 05, 2023

As per the latest NEP-2020 Choice based Credit System (CBCS) Guidelines
University of Kashmir
(2023 onwards)

BOARD OF UNDER GRADUATE STUDIES IN NANOTECHNOLOGY

1.	**Prof. Rabia Hamid** Head Department of Nanotechnology University of Kashmir, Srinagar	*(Chairperson & Convenor)*
2.	**Prof. M Farooq Mir** Department of Physics University of Kashmir, Srinagar	*(Member)*
3.	**Prof. M Ashraf** Consultant, CBCS-UG University of Kashmir, Srinagar *fmr.* Principal, Colleges, Higher Education Department UT of J&K	*(Member)*
4.	**Dr. Farooq A. Khanday** Department of Electronics University of Kashmir, Srinagar	*(Member)*
5.	**Dr. Mushtaq A. Beigh** Department of Nanotechnology University of Kashmir, Srinagar	*(Member)*
6.	**Dr. Faheem Arjamend** Department of Nanotechnology University of Kashmir, Srinagar	*(Member)*
7.	**Dr. Shafquat Majeed** Department of Nanotechnology University of Kashmir, Srinagar	*(Member)*
8.	**Dr. Tariq Maqbool** Department of Nanotechnology University of Kashmir, Srinagar	*(Member)*
9.	**Dr. Khurshed A Shah** Department of Physics S.P. College, Srinagar J&K	*(Member)*
10.	**Nominee of the Chairperson, Board of School Education** UT of J&K	*Member*

CO-OPTED MEMBERS AS SPECIAL INVITED SUBJECT EXPERTS

1.	**Prof. Basharat A Want** **Head, Department of Physics** University of Kashmir Srinagar	*Special Invitee-Subject Expert (co-opted*
2.	**Prof. Aijaz Ahmad Dar** Head Department of Chemistry University of Kashmir, Srinagar	*Special Invitee-Subject Expert (co-opted)*
3.	**Prof. Mukhtar A Khanday** Department of Mathematics University of Kashmir Srinagar & Director, South Campus, University of Kashmir	*Special Invitee-Subject Expert (co-opted)*
4.	**Dr. Nighat Parveen** Head, Department of Biochemistry Govt. College for Women, Nawakadal, Srinagar	*Special Invitee (Colleges)-Subject Expert (co-opted)*

BSc., Honors in Nanotechnology
(Effective from 2023-24 Onwards)

PREAMBLE

The study of Nanoscience sand Nanotechnology involves basic and applied research at the micro and nano levels across a variety of disciplines including chemistry, biology, bioengineering, physics, electronics, clinical and medical science, chemical engineering, and materials science. Globally 'Nanotechnology' is now recognized to be among the few most impacting of sciences that will revolutionize the world in almost every area. Nanotechnology has grown, extensively in the last decade and continues to march ahead in shaping the R&D sector for diverse societal benefits. This advanced 'interdisciplinary' branch has a tremendous networking potential with modern cutting-edge technology. Nanotechnology has already started expanding and growing in the context of its societal impact on global healthcare, agriculture and food security, electronic and automobile industry, providing solutions for environmental issues, renewable energy, space, etc. This has given it a separate status in fundamental research as well as in modern industrial enterprise. Global and local focus has slowly shifted to not only current "Century of Knowledge" but also on to technology development and application in diverse sectors of basic and applied sciences. In the milieu of research and industrialization for economic development and social change, Nanotechnology is an ideal platform to work in. The interdisciplinary nature of Nanotechnology involves many fundamental research fields from material sciences, physics and electronics to devices and sensors, cell biology to molecular biology, from biochemistry to biophysics, from genetic engineering to stem cell research, from bioinformatics to genomics-proteomics, from environment and to biodiversity, from bioremediation to *In silco* drug discovery and so on.

The proposed credit-based NEP-2020 curriculum will add even much more to the existing interdisciplinary nature of Nanotechnology and will also offer many courses to the other branches of Material & Physical Sciences and Life Sciences. The generative power of data at microscale and nanoscale levels is effectively harnessed by Nanotechnology like no other field with relevance and application being extensively covered across diverse areas. Economic and social revolution is significantly staged on Nanotechnology especially, since it's biomedical and cutting-edge technological applications are tremendously powerful in shaping this century and an exciting nano-future. Material science, Life science, IT industries and Research institutes are now on a lookout for trained Nanotechnologists across different disciplines as an efficient work force in fundamental & applied research and industries. Education and research sectors require such interdisciplinary trained workforce to develop future generations of science leaders who will be a part of new age scientific revolution.

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Bachelor of Science (B.Sc.) Honors Program
In
Nanotechnology

Course Structure For Semesters I, II, III & IV

To Be Implemented for Students Admitted
From The Academic Session 2023-24 Onwards
Under
NEP-2020, Choice Based Credit System Pattern

The syllabus and courses of study for Under-Graduate Degree Program- B.Sc. Honors in Nanotechnology, will be based on **98** credits. All the **98** credits will be spread over 8 semesters and shall include different components of 'Teaching' *viz*., (i) Theory Courses (ii) Practical Courses, (iii) Tutorials (in each of the first, second, third, fourth, fifth, sixth, seventh and eighth semesters), and (iv) Research Based Project-work in the eighth semester (for Research mode degree) in accordance with the NEP-2020, guidelines.

Each of the 1st, 2nd, 3rd & 4th semesters will consist of a minimum of **24** credits including the 6 (4+2) credits of Major/Minor course in Nanotechnology being compulsory for BSc Hon, Nanotechnology degree course. Students will earn the remaining credits from other streams as permissible to be opted for under NEP-2020 guidelines. At the end of 2nd semester, students must have earned at least 12 credits from the Major/Minor courses in Nanotechnology, besides the required credits from other streams to continue with UG majors in Nanotechnology.

BSc., Honors in Nanotechnology
(Effective from 2023-24 Onwards)

BSc. Honors Nanotechnology offered as Single/Double Major				
Semester	Course Type 1	Course Type 2	Course Type 3	Total Credits
I	**Essentials of Physics in Nanotechnology** NTY123J1 (4+2) Credits	x	x	6
II	**Essentials of Chemistry in Nanotechnology** NTY223J1 (4+2) Credits	x	x	6
III	**Essentials of Biology in Nanotechnology** NTY323J1 (4+2) Credits	x	x	6
IV	**Mathematical Methods for Nanoscience** NTY423J1 (3+1) Credits	**Fundamentals of Nanoscience** NTY423J2 (4+2 Credits)	**Applied Nanotechnology-I** NTY423J3 (4+2 Credits)	16
V	**Spectroscopy** NTY523J1 (3+1 Credits)	**Synthesis of Nanomaterials** NTY523J2 (4+2 Credits)	**Properties and Applications of Nanomaterials** NTY523J3 (4+2 Credits)	16
VI	**Characterization Techniques** NTY623J1 (3+1 Credits)	**Nanobiosciences** NTY623J2 (4+2 Credits)	**Applied Nanotechnology-II** NTY623J3 (4+2 Credits)	16
VII	**Fundamentals of Electronics** NTY723J1 (3+1 Credits)	**Applied Nanotechnology-III** NTY723J2 (4+2 Credits)	**Advanced Topics in Nanophysics** NTY723J3 (4+2 Credits)	16
VIII	**Nanoscale Electronic Devices** NTY823J1 (3+1 Credits)	**Nanomaterials in Health and Medicine** NTY823J2 (4+2 Credits)	**Nanosensors** NTY823J3 (4+2 Credits)	16
Total Credits	**38**	**30**	**30**	**98**

BSc., Honors in Nanotechnology
(Effective from 2023-24 Onwards)

BSc. Honors Nanotechnology offered as Single/Double Major in Research Mode				
Semester	**Course Type 1**	**Course Type 2**	**Course Type 3**	**Total Credits**
I	**Essentials of Physics in Nanotechnology** NTY123J1 (4+2) Credits	x	x	**6**
II	**Essentials of Chemistry in Nanotechnology** NTY223J1 (4+2) Credits	x	x	**6**
III	**Essentials of Biology in Nanotechnology** NTY323J1 (4+2) Credits	x	x	**6**
IV	**Mathematical Methods for Nanoscience** NTY423J1 (3+1) Credits	**Fundamentals of Nanoscience** NTY423J2 (4+2 Credits)	**Applied Nanotechnology-I** NTY423J3 (4+2 Credits)	**16**
V	**Spectroscopy** NTY523J1 (3+1 Credits)	**Synthesis of Nanomaterials** NTY523J2 (4+2 Credits)	**Properties and Applications of Nanomaterials** NTY523J3 (4+2 Credits)	**16**
VI	**Characterization Techniques** NTY623J1 (3+1 Credits)	**Nanobiosciences** NTY623J2 (4+2 Credits)	**Applied Nanotechnology-II** NTY623J3 (4+2 Credits)	**16**
VII	**Fundamentals of Electronics** NTY723J1 (3+1 Credits)	**Research Methodology** NTY723J4 (4+2 Credits)	**Analytical Tools and Biostatistics** NTY723J5 (4+2 Credits)	**16**
Total Credits (I-VII)	**34**	**24**	**24**	**82**
VIII	**Nanoscale Electronic Devices** NTY823J1 (3+1 Credits)	**Research Based Project** NTY823J4 (12 Credits)		**16**
Total Credits (I-VIII)	**38**	**60**		**98**

BSc., Honors in Nanotechnology
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Semester I (Major Course)	**NTY123J1** **(4+2 Credits) Theory: 04 (60 hrs);** **Lab: 02 (60 hrs/30L)**
Essentials of Physics in Nanotechnology	
COURSE OBJECTIVES	**COURSE OUTCOME**
The students should be able to understand fundamental concepts in physics to be applied in multidisciplinary subjects and be able to design and conduct experiments. The students should be able to identify, formulate, and solve physical and technological problems and use the methods, techniques, skills, and modern scientific tools necessary for different practices in the field of Nanosciences and Technology.	After the completion of the course the students would be equipped with knowledge of fundamental concepts and practices in physics. It will help the students to study different courses in Nanotechnology and will act as foundation stone for higher studies in Nanosciences and its various applied areas.

Unit I **(15 hrs)**

Atomic Physics and Molecular Physics: Black body radiation: Plank's Radiation law (only concept, no derivation), quantization of energy.

Atoms and molecules: J. J. Thomson model, Rutherford's model of atom, Bohr model, drawbacks of Bohr model, hydrogen spectra, excitation potential, ionization potential, electron spin, Pauli's exclusion principal, Zeeman effect, Stark effect. Rotational energy levels, vibrational energy levels, Raman Effect.

UNIT II **(15 hrs)**

Solid State Physics: Bonding in solids, Types of solids and arrangement of atoms in solids, Bravais lattices and their types, Crystal planes and directions, Crystal symmetry, Miller indices, Simple cubic, BCC and FCC crystal structures, Direct and reciprocal lattice, Concept of Brillouin zones.

Schrodinger's wave equations (Time-independent), free particle, particle in one dimensional box, Sommerfeld free electron model, drawbacks of Sommerfeld model.

Unit III **(15 hrs)**

Band Theory of Solids: Motion of electrons in a periodic potential, Kronig Penney model, Bloch theorem, nearly free electron model, Tight binding approximation, Fermi surface of solids; experimental methods, effective mass concept. Band theory of solids, classification of solids on the basis of energy band theory. Doping, Intrinsic and extrinsic semiconductors, direct and indirect band gap semiconductors (GaAs, CdS, Si, Ge), Hall-Effect.

UNIT IV **(15 hrs)**

Thermal, Dielectric, Optical and Magnetic Properties of Solids: Crystal Vibrations - vibration of crystals with monoatomic and two atom per primitive basis, quantization of vibrations-phonons, transverse and longitudinal optical phonons, Dielectric function for electron gas, dispersion relation, plasma frequency, optical reflectance, Kramers-Kronig relations. Diamagnetism, Paramagnetism, Classical theory of Paramagnetism, Ferromagnetism, Curie point and Exchange Integral. Superparamagnetism, Magnons, ferromagnetic domains, single domain particles, Bio-magnetism.

Practicals: (2 Credits) **60 hrs**

1. Determination of Plank's constant using Photoelectric Effect
2. Determination of e/m ratio of electron by J.J. Thomson's method
3. To observe the quantum of nature of charge using Millikan Oil Drop setup.
4. To determine the energy gap of a semiconductor using Four probe method.
5. To determine the Hall coefficient for a semiconductor sample.
6. To determine the characteristics of a junction diode.
7. To determine the characteristics of a bipolar junction transistor.
8. Determination of Rydberg's constant using Hydrogen discharge tube.
9. To determine the wave length of a laser with a diffraction grating.
10. To Determination of e/m ratio of electron by Helical method

Books & References

1. Atomic and Molecular Spectra: Laser, Raj Kumar 5th ed. Kedarnath Ramnath Publishers, Delhi, 2019
2. Concepts of Modern Physics, Arthur Beiser, 6th ed. Mc Graw Hill; Kent A. Peterson Publishers, 2003
3. Atomic Physics, J. B. Rajam, 7th ed. S. Chand and Co., Delhi, 2010
4. Introduction to Solid State Physics: Charles Kittel, Wiley, 8th ed. Wiley & Sons, 2004
5. Solid State Physics, S.O. Pillai, 8th ed., New Age International, 2018
6. Elementary Solid-State Physics-Principles and Applications, M. Ali Omar, Pearson, 2002
7. Solid State Physics, A. J. Dekker, Macmillan India Ltd, 2004
8. B.Sc. Practical Physics by CL Arora; S. Chand Publishing, 2001
9. B.Sc. Practical Physics by Harnam Singh, S. Chand Publishing, 2000

Semester II (Major Course)	NTY223J1 (4+2 Credits) Theory: 04 (60 hrs); Lab: 02 (60 hrs/30L)
Essentials of Chemistry in Nanotechnology	
COURSE OBJECTIVES	**COURSE OUTCOME**
This course places its emphasis on imparting the essential concepts and principles of chemistry necessary for comprehending the various aspects of Nanoscience and Nanotechnology.	The successful completion of this course will not only enable the students to understand the underlying principles of Nanoscience and Nanotechnology but this course will also act as the stepping stone for grasping the more advanced concepts encountered towards the end of this programme.

Unit I **(15 hrs)**

Atomic Structure: Wave Mechanical concept of Atomic Structure: de-Broglie's wave equation; derivation and experimental verification. Heisenberg's Uncertainty Principle: Illustration and significance. Confirmation of quantization of angular momentum and its significance.
Wavefunction and its significance, radial and angular wave functions for hydrogen atom. Radial and angular distribution curves; Shapes of s, p & d orbitals; Effective nuclear charge and its calculation by Slater rules.
Periodic Properties: Trends in Atomic, Ionic, Metallic and Van der Waal radii. Successive ionization energies and factors affecting ionization energy. Electronegativity and Electron Affinity: Trends, Methods of determination; Applications in predicting and explaining the chemical behavior of elements.

Unit II **(15 hrs)**

Chemical Bonding: Ionic Bond: Lattice energy and Born Haber Cycle. Factors affecting the structure of ionic solids; Radius ratio effect; Coordination number and limitations of radius ratio rule. Fajan's rules and its applications.
Solvation energy and solubility of ionic solids. Factors affecting the solubility of ionic solids.
Metallic bond: Characteristics, comparison with ionic and covalent bonds.
Types of intermolecular forces: Hydrogen bonding, Dipole-dipole forces, London forces and ion-dipole forces. Significance of such forces.
Valence bond theory: Directional characteristics of covalent bond and types of hybridizations. Limitations of VB theory. Percent ionic character from dipole moment and electronegativity difference.
VSEPR theory: Assumptions; Shapes of some molecules (BF_3, NH_3, H_2O, SF_4, ClF_3 and XeF_2)
Molecular Orbital Theory: Energy level diagrams, Bond order with its significance and application to simple molecules (N_2, O_2, HCl and CO).

Unit III **(15 hrs)**

Basic Concepts in Organic Chemistry: Inductive and Electromeric effects. Conjugation, Resonance and Hyperconjugation. *Reactive intermediates:* Structure, generation and stability of Carbocations, Carbanions, Free radicals,
Carbenes, Benzynes and Nitrenes.
Concept and types of stereoisomerism. Geometrical Isomerism: Configuration of geometrical isomers. E and Z system of nomenclature. Optical Isomerism: Elements of symmetry, molecular chirality, chiral and achiral molecules with two stereogenic centers. Enantiomers, diastereoisomers and Meso compounds. Resolution of enantiomers. Inversion, retention and racemization. Relative and absolute configurations. D, L and R, S systems of nomenclature.

Unit IV **(15 hrs)**

Essential Concepts in Physical Chemistry: Order of reaction; derivation of rate equations for second and third order reactions (one reactant only). Determination of order of reaction by differential rate, integration, half-life period and isolation methods. Temperature dependence of reaction rates: Arrhenius equation, concept of activation energy.
Thermodynamic functions: State and path functions and their differentials. Thermodynamic processes. Concept of heat and work. Heat capacity, heat capacities at constant volume and constant pressure and their relationship. Joule's law, Joule-Thomson coefficient and inversion temperature.
Equilibrium: Concept of Free energy, Equilibrium constant and free energy change. Reaction isotherm and reaction isochore, Clapeyron equation and Clausius-Clapeyron equation, applications. Phase rule: Meaning of the terms: phase, component and degree of freedom, statement of Gibbs phase rule, phase diagrams of one component system – water.
Electrochemistry: Arrhenius theory of electrolyte dissociation and its limitations. Migration of ions and Kohlrausch's law, Debye-Huckel-Onsager's equation for strong electrolytes (elementary treatment).

Practicals (2 credits) **60 Hours**

1. Preparation of solutions of different concentrations; Standardization of solutions (acids and bases).
2. Volumetric estimation of oxalic acid by titrating it with $KMnO_4$.
3. Determination of ferrous ions by dichromate method using titrimetric method.
4. Purification of organic compounds by crystallization (from water and alcohol) and sublimation.
5. Detection of N, S and halogens in organic compounds.
6. Measurement of density and relative density of various liquids using pyknometer/density bottle.
7. Determination of heat capacity of calorimeter for different volumes.
8. Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide

Books and References:

1. Basic Inorganic Chemistry; F.A. Cotton, G Wilkinson & P.L. Gauss; 3rd ed.; Wiley; 2002.
2. Concise Inorganic Chemistry; J.D. Lee; 5th ed.; ELBS; 2003
3. Inorganic Chemistry; D.E. Shriver; P.W. Atkins & C.H. Langford; 4th ed.; Oxford; 2006
4. Principles of Physical Chemistry; Puri, Sharma and Pathania; S. Nagin Chand & Co; 2011

5. Physical Chemistry; A Molecular Approach, McQuarie, Viva Pvt. Ltd., 2021
6. The Elements of Physical Chemistry; P. W. Atkins; 7th ed., Oxford University Press; 2016
7. Organic chemistry (8th Ed); Bruice, Paula Yurkanis, Pearson Prentice Hall, 2007
8. Organic Chemistry by John E McMurry (8th Edition) Pearson Education, 2011
9. Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.
10. Mendham, J. *Vogel's Quantitative Chemical Analysis*, Pearson, 2009.
11. Comprehensive Practical Organic Chemistry: Qualitative analysis Ahluwalia, V.K. & Sunita Dhingra; Universities Press, India, 2004.
12. Advanced Practical Organic Chemistry; N. K. Vishnoi; 3rdEdn; Vikas Publishing, 2009.
13. Advanced Practical Physical Chemistry; J.B. Yadav; Krishna Prakashan Media (P) Limited, 2015.
14. Advanced Physical Chemistry Experiments; J. N. Gurtu, A. Gurtu, Pragati Prakashan, 2008.

Semester III (Major Course)	NTY323J1 (4+2 Credits) Theory: 04 (60 hrs); Lab: 02 (60 hrs/30L)
Essentials of Biology in Nanotechnology	
COURSE OBJECTIVES	**COURSE OUTCOME**
This course aims to familiarize students with biological concepts, properties and organization of biomolecules including nanoscale molecules in biology, along with an understanding of cell biological perspectives.	Completion of this course will enable students to develop a basic understanding of biomolecules, their properties and functions to make it coherent with their understanding of disease and applications of nano-biologicals in therapeutics and molecular diagnostics in later semesters. In particular the student will be able to: ▪ Classify carbohydrates, lipids, proteins and nucleic acids into different types and know about their structure & functions in the biological system. ▪ Know about cell and organelle structure, membrane structure and transport, with an overview of signal transduction and machines/motors in biological systems. ▪ Have a fundamental concept of enzymes and their function and learn about their role in metabolism.

Unit I **(15 hrs)**

Carbohydrates: General Description and properties of carbohydrates and their importance in biological system. Monosaccharides, Disaccharides and Polysaccharides their structure and Function. Complex carbohydrates. Role of carbohydrates in cell recognition and energy metabolism, Glycolysis, Tricarboxylic Acid Cycle.

Lipids: Definition and classification of Lipids. Fatty acids and triglycerides, their structure, properties and types. Role of lipids in membrane structure, cell recognition and energy metabolism, β-oxidation.

Unit II **(15 hrs)**

Nucleic acids: Definition and significance of Nucleic acids in living systems. Structure of DNA and RNA. Forms of DNA and semi-conservative DNA replication. RNA- mRNA, rRNA and tRNA, structure and function. Concept of genetic code-Codons and anti-codons.

Proteins: Definition and classification of proteins. Protein structure and function: Amino acids, peptide bond, peptides and primary structure. Secondary structure-α-helix, β- sheet and turns. Tertiary and quaternary structure. Protein folding: forces responsible for protein stability and role of solvent.

Unit III **(15 hrs)**

Cell structure: Cell types and sizes. Milestones in cell biology. Structure and function of: Cell membrane, Nucleus, Endoplasmic reticulum, Golgi apparatus, Mitochondria, Chloroplasts, Lysosomes, Peroxisomes.

Cell organization: Single celled organisms and concept of multicellularity. Cell adhesion and extracellular matrix. Cell communication: cell-cell junctions.

Unit IV **(15 hrs)**

Protein complexes and their functions: Structural Protein Complexes- Role of membrane proteins in cellular organization. Transporters, ion channels, and receptor complexes. Signal transduction complexes (Basic idea involving intracellular messengers). Cytoskeleton: role in structural strength and mechanical stress, Microtubules, actin filaments, and intermediate filaments. Motor proteins and intracellular transport.

Protein complexes in metabolic pathways- Enzymes-definition, classification and functions. Enzyme substrate interactions. Enzyme inhibition- Competitive, Non-competitive and Un-competitive (*without derivations*). Enzyme regulation- role of coenzymes and cofactors.

Practicals (2 credits: 60 Hours)

1. Qualitative tests for carbohydrates, lipids and proteins.
2. Estimation of protein concentration by Lowry's method or Biuret method.
4. Determination of absorption spectra of DNA and protein using UV-Visible spectrophotometer.
5. Estimation of DNA by Diphenylamine reaction.
6. Estimation of RNA by Orcinol method
7. Agarose Gel electrophoresis and Quantification of DNA and RNA.
8. Enzyme assay and determination of specific activity of enzyme.
9. Separation of proteins by Polyacrylamide Gel Electrophoresis (PAGE).

References:

1. Lehninger's Principles of Biochemistry by D. L. Nelson and M. M. Cox, CBS Publications, 8th Edition, 2021.
2. Molecular Cell biology by Harvey Lodish, W.H Freeman 2016.
3. Enzymes: Biochemistry, Biotechnology, Clinical Chemistry by Trevor Palmer, Horwood Publishing Ltd, 5th edition, 2001.
4. Practical Biochemistry: An Introductory Course by Fiona Frais. University Park Press, 2016
5. A Textbook of Practical Biochemistry by David Plummer McGraw Hill Education; 3 edition 2017.

Semester IV (Major Course)	NTY423J1 (3 +1Credits) Theory: 03 (45 hrs); Tutorials: 01 (15hrs)
Mathematical Methods for Nanoscience	
COURSE OBJECTIVES: This course aims to focus on the mathematical techniques to deal with the problems of nanomaterials. The course will help the students to understand properties and applications of nanosciences with optimal conditions.	**COURSE OUTCOME:** After the successful completion of this course, students shall be able to apply mathematical tools to understand allocation, rate of change of materials and concentration of nanomaterials.

(Theory-3 Credits)

Unit I **(15 hrs)**

Matrix theory: Algebra of matrices, types of matrices, adjoint of a matrix, inverse of a matrix. Transpose of a Matrix, Conjugate Transpose of a Matrix, Symmetric and skew-symmetric matrices, Hermitian and skew-Hermitian matrices, Matrix polynomials: Characteristic equation, Eigenvalues and eigenvectors; Cayley-Hamilton Theorem (statement only), minimal polynomials, stablity of systems using eigenvalue concepts.

Unit II **(15 hrs)**

Functions, limits and continuity, derivative of a function, rules for differentiation, applications of the derivative, maxima and minima, increasing and decreasing functions. Basic idea of definite integrals, area of a bounded region. Differential equations and their solutions, variables separable method, exact differential equations, homogeneous form, linear differential equations of the form $dy/dx + py = Q$, applications of differential equations in radioactive decay, growth and related systems.

Unit III **(15 hrs)**

Basic statistics: mean, median, mode standard deviation, correlation, regression methods & techniques, Measures of central tendency: Arithmetic, geometric and harmonic mean. Measures of dispersion, skewness and kurtosis. Correlation and regression. Introduction to probability theory: sample space, event, probability of an event. Conditional probability. Independence of events. Random variables and probability distributions. Basic idea of Binomial and normal distributions. Estimation of population parameters from sample data.

Unit IV (Tutorial) **(15 hrs)**

Review of matrix algebra, Gauss elimination method, Gauss-Siedal iterative method, Numerical differentiation and numerical integration: Newton's forward and backword difference methods, Trapezoidal method, simpson $1/3^{rd}$ and $3/8^{th}$ methods.

Books and References:

1. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons, 2019.
2. Shanti Narayan and PK Mittal, A Text Book of Matrices, S. Chand and company Ltd, 2010.
3. S.D. Chopra and M.L. Kochar, Integral Calculus, Kapoor Publications, 2021 edition.
5. M.R. Spiegel, Theory and Problems of Probability and Statistics (Schaum Series), 2003
6. S.S. Sastry, "Introductory methods of Numerical Analysis, 5th Editions, PHI, New Delhi, 2012

BSc., Honors in Nanotechnology
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Semester IV (Major Course)	NTY NTY423J2 (4+2 Credits) Theory: 04 (60 hrs); Lab: 02 (60 hrs/30L)
Fundamentals of Nanoscience	
COURSE OBJECTIVES	**COURSE OUTCOME**
By the end of this course, students should be able to: understand nanomaterials, explore size-dependent phenomena, trace historical developments, evaluate environmental impact and safety, evaluate environmental impact and safety, navigate ethical and regulatory considerations, evaluate environmental impact and safety.	The successful completion of this course will enable fundamental understanding of nanomaterials, define nanomaterials, their properties, applications, ethical considerations, and their role in shaping various industries and technologies.

Unit I **(15 hrs)**

Definitions, Relationship and Differences. Nano and Nature: Nanoscopic Colors (Butterfly Wings), Bioluminescence (Fireflies), Tribology (Geckos sticky feet, lotus leaf effect). Nanotechnology timeline, Pre-18th Century, 19th Century, 20th Century and 21st Century. Role of advanced instrumentation in the Nanotechnology revolution. Future perspectives of nanoscience and nanotechnology. Regulation and ethical considerations in nanotechnology. Environmental impact of nanomaterials, Health and safety concerns.

Unit II **(15 hrs)**

Scale of materials – macro, micro and nanoscale. Difference between nanoscience and nanotechnology and its interdisciplinary nature. Feynman's vision of nanoscience and nanotechnology. Types of nanostructures - Introduction to zero dimensional (examples of metal, semiconductor and carbon-based nanoparticles like fullerenes, carbon dots), one dimensional (examples of carbon nanotubes - single-walled or multi-walled) and two-dimensional nanomaterials like graphene and graphene oxide.

Unit III **(15 hrs)**

Surface dependent effects, surface to volume ratio of nanomaterials in comparison to bulk materials. Calculation of surface to volume ratio of some model geometries (cylinder, sphere, cube and a plane). Significance of nanomaterials, Properties of nanomaterials: Elementary idea about size-dependent phenomena in metal and semiconductor nanoparticles. Effect of nanoparticle size on the band gap of semiconducting nanoparticles. Idea about Surface plasmon resonance in metallic nanoparticles.

Unit IV **(15 hrs)**

Colloidal Nanoscience: Introduction to colloidal materials, surface properties, origin of colloidal particles, preparation & characterization of colloidal particles. Applications of super hydrophilic and hydrophobic surfaces, self-cleaning surfaces. Surface viscosity.

Surface Nanoscience: Introduction to surface active agents. Theory and applications. Types of surfactants. Micelles, Emulsions, Microemulsions.

Nanoscience and Interface: Intermolecular Forces, Van der Waals forces. Dynamic properties of interfaces. Contact angle, Brownian motion and concept of surface free energy.

Nanoscience and Interface: Intermolecular Forces, Van der Waals forces. Dynamic properties of interfaces. Contact angle, Brownian motion and concept of surface free energy.

Practicals (2 credits) **60 Hours**

1. To study the relation between nanostructures and properties of natural nanomaterials like milk, gelatine, Gecko's feet, butterfly wings.
2. Students research and create a timeline of significant nanotechnology discoveries from the pre-18th century to the 21st century.
3. Synthesis of gold nanoparticles by Turkevich method and the observation of colour changes in Au colloids due to the addition of salt, sugar which result in aggregation of Au nanoparticles.
4. Synthesis of different sized Ag nanoparticles by chemical reduction method and comparison of their UV-Visible spectrum

Books and References:

1. Introduction to Nanotechnology" by Charles P. Poole Jr. and Frank J. Owens, Wiley, 2003
2. Nanotechnology: An Introduction" by Jeremy Ramsden, 2012
3. John Mongillo, Nanotechnology 101, Greenwood Press, 2007
4. Gabor L. Hornyak, Joy Deep Dutta, Harry F. Tibbals and Hail K. Rao, Introduction to Nanoscience, New York, CRC press, 2008, Chapters: Unit: I, IV & V
5. Pradeep T, Nano: The Essentials: Understanding Nanoscience and Nanotechnology, New Delhi, Tata McGraw-Hill Publishing Company Limited, 2008
6. A laboratory course in Nanoscience and Nanotechnology by Gerrard Eddy Jai Poinern, 1st edition, 2015, CRC Press
7. Turkevich Method for Gold Nanoparticle Synthesis Revisited; J. Kimling, M. Maier, B. Okenve, V. Kotaidis, H. Ballot, and A. Plech; J. Phys. Chem. B 2006, 110, 32, 15700–15707
8. https://www.nano.gov/
9. https://nanoyou.eu/component/content/article/87-hands-on-activities/499-experiment-on-natural nanomaterials-nanotechnology-education-resources0e28.html?directory=4&Itemid=4

Semester IV (Major Course)	NTY NTY423J3 (4+2 Credits) Theory: 04 (60 hrs); Lab: 02 (60 hrs/30L)
Applied Nanotechnology-I	
COURSE OBJECTIVES	**COURSE OUTCOME**
The course deals with understanding structure and properties of different forms of carbon and their use in producing various carbon-based nanomaterials through different methods. It focuses on their applications in diverse areas of electronics, energy, environment and biology. The latter half of the course provides an understanding of the basics, importance and role of nanomaterials for their biomedical applications in targeted drug delivery as well as applications in various aspects of environment.	By the end of this course, students will have gained a comprehensive understanding of different forms of carbon-based nanostructures and their applications in nanotechnology. They will also be well versed with basics of Nanobiotechnology and its importance in biomedical sciences in terms of drug delivery and detection and remediation of environmental pollutants. Successful completion of the course will equip them with the knowledge to critically assess and contribute to the evolving field of Nanotechnology's impact on these domains.

Unit I **(15 hrs)**

Carbon nanotubes and Buckminster Fullerenes – structure and properties. Production of carbon nanotubes (Single walled and multi walled) and fullerenes: arc discharge method, Laser ablation, Chemical Vapour deposition, Pyrolytic technique. Purification and separation of carbon nanotubes, diamond synthesis routes, preparation of nanodiamond.

Unit II **(15 hrs)**

Optical, Electrical, thermal and mechanical properties of different allotropes of carbon-based nanomaterials. Applications of carbon-based nanomaterials: Catalysis applications of nanoforms of carbon, supercapacitor, battery applications, water purification, solar cell applications, sensor and FET, Biological applications.

Unit III **(15 hrs)**

Nanobiotechnology: historical development, milestones, significance in biological research. Types of nanoparticles used in drug delivery (liposomes, polymeric nanoparticles, dendrimers, etc.). Introduction to drug delivery systems- Advantages of using nanoparticles for drug delivery, nanoparticles surface modification, bio-conjugation, PEGylation, Drug encapsulation and controlled release (sustained and triggered).

Unit IV **(15 hrs)**

Introduction to environmental nanotechnology and its importance. Nanomaterials for water purification and treatment. Classifications and source of pollutants - Air - Water - Soil - biomarkers – Environmental implication of nanomaterials – Occurrences, Fate and characterization of nanomaterials in the environment. Applications of Nanotechnology in air quality control and pollution detection.

Practicals (2 credits) **60 Hours**

1. Analysis of candle soot under a scanning electron microscope and its compositional details by elemental dispersive spectroscopy
2. Synthesis of fluorescent carbon nanoparticles from candle soot and their separation by thin layer chromatography
3. Preparation of carbon nanotubes from graphite powder and observation of their tubular morphology under SEM.
4. Protein quantification by Fluorescence spectroscopy/ELISA.
5. Isolation, quantification and purification of genomic DNA.
6. Studying Drug Diffusion on agar plates
7. Serum albumin nanoparticles: Preparation and effect of pH / cross linking agent
8. Testing the Effectiveness of Nanomaterials like Ag, TiO_2, graphene oxide, carbon based etc. in water Purification

Books and References:

1. Carbon materials and Nanotechnology – Anke Krueger, Wiley- VCH publication, 2010
2. Carbon Nanotube Science, Peter J. F. Harris, Cambridge University Press, 2009
3. Gabor L. Hornyak, Joy Deep Dutta, Harry F. Tibbals and Hail K. Rao, Introduction to Nanoscience, New York, CRC press, 2008
4. Bionanotechnology: Principles and Applications. Anil Kumar Anal. CRC Press, Taylor & Francis Group (2018)
5. Environmental Nanotechnology: Applications and Impacts of Nanomaterials, 2nd Edition Mark R. Wiesner & Jean-Yves Bottero, 2007
6. Environmental Nanotechnology by M. H. Fulekar, Bhawana Pathak, 1st edition, 2017
7. A laboratory course in Nanoscience and Nanotechnology by Dr. Gerrard Eddy Jai Poinern, CRC Press, 2014
8. Preparation of carbon nanotubes from graphite powder at room temperature; Lee, D. W., Seo, J. W. https://doi.org/10.48550/arXiv.1007.1062 ; 2010
9. Nanoparticle- and Microparticle-based Delivery Systems: Encapsulation, Protection and Release of Active Compounds, David Julian McClements, CRC Press, 2014