

Department of Physics
Programme: M.Sc. (Nano Sci. and Technol.)
 Course Structure and Syllabus of M.Sc. in Nanoscience & Technology
 Minimum Credit requirement: 85
 Minimum duration: 2 years (4 semesters)
 Maximum duration: 4 years (8 semesters)

COURSE STRUCTURE

Semester I

Course Code	Course Name	L-T-P	CH	CR	Remarks
NS-415	Mathematical Methods	2-1-0	3	3	
NS-416	Electrodynamics	2-1-0	3	3	
NS-418	Quantum Mechanics-I	2-1-0	3	3	
NS-408	Condensed Matter Physics	2-1-0	3	3	
NS-404	Basic polymer science	2-1-0	3	3	
NS-400	Laboratory- I	0-0-4	8	5	Physics/Chemistry/Biology based
	CBCT			3	CBCT list
Total Credits				23	

Semester II

Course Code	Course Name	L-T-P	CH	CR	Remarks
NS-453	Atomic and Molecular Spectroscopy	2-1-0	3	3	
NS-421	Statistical Physics	2-1-0	3	3	
NS-402	Electronics	2-1-0	3	3	
NS-410	Nanostructures	2-1-0	3	3	
NS-498	Laboratory- II	0-0-4	8	5	Physics/Chemistry/Biology based
NS-455	Seminar	0-0-2	4	2	
	CBCT			3	CBCT list
Total Credits				22	

Semester III

Course Code	Course Name	L-T-P	CH	CR	Remarks
NS-500	Project work -I	0-0-8	12	6	<i>To be carried out under the guidance of faculty member(s)</i>
NS-552	Quantum Mechanics-II	2-1-0	3	3	
NS-501	Surface Science	2-1-0	3	3	
NS-553	Biophysics and Nanobiotechnology	2-1-0	3	3	
NS-554	Computation and Modeling Techniques	0-1-3	7	4	
	CBCT			3	CBCT
Total Credits				22	

Semester IV

Course Code	Course Name	L-T-P	CH	CR	Remarks
NS-599	Project work-II	0-4-8	24	12	<i>To be carried out under the guidance of faculty member(s)</i>
NS-559	Nanophotonics	2-1-0	3	3	
NS-558	Nanomagnetism	2-1-0	3	3	
Total credits				18	

L: Lectures; T: Tutorials; P: Practical; CH: Contact Hours; (all per week); CR: Credits

Total Credits: $(23 + 22 + 22 + 18) = 85$

Credits in Lab & Project: $(5 + 5 + 6 + 12) = 28$

Total Credits excluding Lab & Project: = **57**

Total credits in CBCT: $(3+3+3) = 09$

Semester I

NS-415 Mathematical Methods

(L2-T1-P0-CH3-CR3)

Scalar and vector fields, differentiations, divergence and curl; integrations, Greens, Gauss's and Stokes theorems and their applications, transformations of coordinate systems and vector components, metric coefficients, curvilinear coordinates; expressions for grad., div., and curl; Helmholtz equation in three-dimensions and separable variables in various coordinate systems; matrices and determinants,

Beta, gamma and error functions; relationship between the beta and gamma functions; reduction of some classes of integrals to gamma functions; Sterling's formula; derivation of values of gamma functions, Fourier series: Evaluation of coefficients, graphical representations, even and odd functions, properties of Fourier series, Fourier integrals.

Ordinary differential equations, second-order homogeneous and inhomogeneous equations, Wronskian, general solutions; adjoint of a differential equation, ordinary and singular points, series solution; Legendre, Hermite, Laguerre and the associated polynomials, their differential equations, generating functions; Bessel functions, spherical Bessel equations, integral representation of special functions. Dirac delta function.

Green function, Partial differential equations in physical problems: Laplace's equation, Poisson's equation, Heat flow equations, Wave equations, Helmholtz equations; solutions of these equations; eigenvalue problems, boundary value problems, method of separation of variables.

Integral transforms: Laplace transform, Hankel transform, Mellin transform, Fourier transform, Properties of Laplace and Fourier transforms, application of Laplace and Fourier transformations.

Textbooks:

1. Harper, C., *Introduction to Mathematical Physics*, (Prentice Hall, 2009)
2. Arfken, G. B., and Weber, H. J., *Mathematical Methods for Physicists*, (Elsevier Ltd, Oxford, 2005)

Reference Books

1. Morganeau, H. and Purphy, C. M., *The Mathematics of Physics and Chemistry*, (Young Press, 2009)
2. Spiegel, M. R., *Vector Analysis*, Schaum's outline series, (Tata McGraw-Hill 1979)

NS-416 Electrodynamics

(L2-T1-P0-CH3-CR3)

Electrostatics and magneto-statics: Gauss's law in differential and integral forms, The electric dipole, its electric field and potential, The capacitance of parallel plate, Cylindrical and spherical capacitors, Magnetic effects in the absence of magnetic media: the Biot-Savart law, the force on a current and on moving charges in a B-field, the magnetic dipole, The couple and force on, and the energy of, a dipole in an external electric field and in an external magnetic field.

Method of images, boundary value problems, Laplace equation in rectangular, cylindrical and spherical coordinates, multipole expansion, Gauge transformation, Coulomb and Lorentz gauges.

Maxwell's equations, conservation of energy and momentum in electrodynamics, Poynting Theorem, Maxwell's stress tensor, Wave equation, reflection, refraction and propagation of electromagnetic waves in dispersive media, wave equation in a conducting medium.

Wave-guides and cavity resonance, EM wave propagation of various types of EM modes in different types of wave guides.

Textbooks:

1. Griffiths, D. J., *Introduction to Electrodynamics*, (Prentice-Hall India, 2009)
2. Jackson, J. D., *Classical Electrodynamics*, (Wiley, Eastern Ltd, 3rd edition, 1998)

Reference Books:

1. Reitz, J. R. and Millford, F. J., *Foundations of Electromagnetic Theory*, (Prentice Hall India)
2. Slater, J. C., and Frank, N. H., *Electromagnetism*, (Dover Publications, 2011)
3. Miah, W., *Fundamentals of Electromagnetism*, (Tata McGraw Hill, 1982)
4. Feynman, R. P., *Feynman Lecture Series Volume II*, (Addison Wesley Longman, 1970)

NS-418 Quantum Mechanics-I (L2-T1-P0-CH3-CR3)

Review of wave-particle duality, uncertainty principle and Schrodinger equation, orthonormality and orthogonality , application of Schrodinger equation to H-like atoms.

Hilbert space formalism for quantum mechanics, Dirac notation, linear operators, Hermitian operator, projection operators, unitary operators, eigenvalues and eigen vectors of an operator.

Matrix representation of Kets, Bras and Operators, harmonic oscillator and its solution by matrix method, The basic postulates of quantum mechanics, superposition principle, expectation value, Heisenberg equation of motion.

Angular momentum in quantum mechanics, commutation relations, eigen functions of orbital angular momentum, spin angular momentum, Pauli spin matrices.

Textbooks:

1. Schiff, L. S., *Quantum Mechanics*, (Tata McGraw-Hill Education)
2. Ghatak, A. K. and Lokanathan, S., *Quantum Mechanics: Theory and Applications*, (Springer, 2002)

Reference Books:

1. Waghmare, Y. R., *Fundamentals of Quantum Mechanics*, (Wheeler publishing)
2. Mathews, P. M. and Venkatesan, K., *Quantum Mechanics*, (Tata McGraw-Hill Education, 2007)
3. Pauling, L., *Introduction of Quantum Mechanics*, (McGraw-Hill)
4. Dirac, P. A. M., *Principles of Quantum Mechanics*, (Oxford University Press)
5. Kemble, E. C., *The Fundamental principles of Quantum Mechanics*, (McGraw-Hill)

NS-408 Condensed Matter Physics and Material Science (L2-T1-P0-CH3-CR3)

Review of elements of crystallography and typical crystal structures, Crystal diffraction, reciprocal lattice, atomic form factor, structure factor and Debye-Waller factor, x-ray, electron and neutron diffractions.

Lattice vibration in solids: Enumeration of modes, monoatomic linear chain, infinite and finite boundary conditions, dispersion relation, diatomic chain, acoustical and optical modes, quantization of lattice vibrations (phonons).

Einstein and Debye theory of specific heat of solids, free electron theory of metals, electronic specific heat, electrical conductivity, thermal conductivity, Wiedemann-Franz law.

Motion of electrons in periodic potential, Bloch theorem, Kronig Penney model, band theory of solids, Brillouin zones; insulators, semiconductors and metals, Fermi surface, holes, intrinsic and extrinsic semiconductors, concept of effective mass and law of mass action, Hall effect and magnetoresistance.

Inelastic neutron scattering, analysis of data by generalized Ewald construction, dispersion relations, frequency distribution function, thermal conductivity of insulators, Normal and umklapp processes, crystal imperfections, colour centres, linear and edge dislocations, Bergers' vector, thermo-luminescence

Textbooks:

1. Kittel, C., *Introduction to Solid State physics*, 7th Edition (Wiley, Eastern Ltd., 1996)
2. Burns, G., *Solid State Physics*, (Academic press, 1995)
3. Dekker, A. J., *Solid State Physics*, (Macmillan India Ltd., 2003)

Reference Books:

1. Ibach, H. & Luth, H., *Solid State Physics*, (Springer-Verlag, 1993)
2. Patterson, J. D., *Introduction to the Theory of Solid State Physics*, (Addison-Wesley, 1971)
3. Ashcroft, N. W. & Mermin, N. D., *Solid State Physics*, (Saunders, 1976)

NS-404 Basic Polymer Science (L2-T1-P0-CH3-CR3)

Basic nature and classification, importance of polymers as a class of material, polymers raw materials.

Special features of polymerization, techniques of polymerization : mass, solution, suspension, emulsion and gas phase: molecular weight and molecular weight distribution, control of molecular weight, step polymerization, radical chain polymerization, living and non-living chain polymerization ring opening polymerization.

Stereochemistry of polymers, modification of polymers, cross linking, polymer architecture, structure property relation.

Polymer processing and fabrication, polymers, future prospects.

Conductivity range of commercial polymers, synthesis of conducting polymers, polyacetylene and derivative, polypyrrole, polyaniline, polythiophene, polyphenylene, sulfide and others containing heteroatoms in the chain).

Electrochemical and photochemical polymerization, synthesis via precursor polymer, doping and dopants, electrical and optical properties, environmental stability, narrow bandgap conducting polymers, self doped polymers, mechanisms of electrical conduction in polymers, solutions, polarons, bipolarons, applications.

Textbooks:

1. Gowariker, V. R., Viswanathan, N. V. and Sreedhar, J., *Polymer Science*, (Wiley Eastern, Calcutta, 1986).
2. Misra, G. S., *Introductory Polymer Chemistry*, (Wiley Eastern, Calcutta 1993).
3. Seymour, R. B. and Carraher, C. E., *Polymer Chemistry: An Introduction*, 2nd Edition (Marcel Dekker, New York, 1989).

Reference Books:

1. Ghosh, P., *Polymer Science and Technology of Plastics and Rubbers*, (Tata McGraw Hill, New Delhi, 1990).
2. Baijalal, M. D., *Polymer Science & Technology*, (Wiley, New York, 1981).
3. Alcazar, L., *Conducting Polymers*, (Kluwer Academic, Hingham, Massachusetts, 1981).
4. Chandrasekhar, P., *Conducting Polymers*, (Kluwer Academy, 1999).
5. Skotheim, A., *Handbook of Conducting Polymers*, (Dekker, USA, 1986).

NS-400 Laboratory- I

(L0-T0-P4-CH8-CR4)

Physics based Experiments

1. To determine the velocity of sound in (a) dry air, and (b) rods by Kundt's tube method.
2. To determine the difference in wavelength between atomic transition lines and Zeeman lines using Zeeman effect setup (SES instruments Pvt. Ltd.)
3. To determine the diameter of thin wire using (a) interference, and (b) diffraction methods and hence, compare the results.
4. To determine dielectric constant of the ceramic specimen using given experimental setup based on parallel plate capacitor configuration.
5. To study dispersion curves for mono and diatomic lattices using lattice dynamic kit.
6. To determine the e/m ratio of an electron by using Millikan oil drop experiment.
7. To draw resistivity vs. temperature plot for a semiconducting specimen using Four probe method and then, calculate energy gap of the specimen under study.
8. To study, take measurement and prepare a report on:
 - a) UV-VIS-NIR spectroscopy
 - b) Photoluminescence spectroscopy
 - c) X-ray diffraction method

Chemistry based Experiments

1. Aqueous method: To synthesize cadmium sulfide nanoparticles in a polymer matrix and determine particle size using spectroscopic and diffraction tools.
2. Non-Aqueous method: To synthesize barium titanate nanopowders via solid state reaction route and study temperature dependent growth of average crystallite size using XRD data.

Biology based Experiments

1. Identification of biological specimens and tissue sections
2. Protein estimation and SDS PAGE electrophoresis

Semester II

NS-453 Atomic and molecular spectroscopy (L2-T1-P0-CH3-CR3)

Line spectra and band spectra, Atomic excitation and de-excitation processes, Atomic absorption and emission spectra (AAS and AES), series spectra in alkali and alkaline earths, LS and JJ coupling in central field approximation. Selection rules, allowed and forbidden transitions. Spin-orbit coupling. *sp-d* exchange interaction in transition metals, *D-F* transitions in rare earth systems.

Spectra of diatomic molecules, pure rotation, pure vibration; vibration-rotation and electronic spectra, Born-Oppenheimer approximation and its application to molecular spectroscopy, formation of bands, structure of bands, dissociation and pre-dissociation, valence-bond theory, molecular orbital theory, bonding and anti-bonding of electrons for equal nuclear charges, energy level of symmetric top molecules, potential energy function.

Morse potential function, Raman spectroscopy, electron spin resonance (ESR) spectroscopy, nuclear magnetic resonance (NMR) spectroscopy, Mossbauer spectroscopy.

Textbooks:

1. Beiser, A. and Mahajan, S., *Concepts of Modern Physics*, 6th edition, (McGraw Hill Education (India) Private Limited, 2009)
2. Herzberg, G., *Atomic Spectra and Atomic Structure*, 2nd edition, (Dover Publications, 2010)
3. Banwell, C. N. and McCash E. M., *Fundamentals of Molecular Spectroscopy*, (McGraw-Hill, 1994)

Reference Books:

1. Kuhn, H. G., *Atomic Spectra*, (Longmans, 1969)
2. Ruark, A. E., and Urey, H. C., *Atoms, Molecules and Quanta*, (McGraw-Hill, 1930)
3. Siegman A. E., *Lasers*, (University Science Books, 1986)
4. White, H. E., *Introduction to Atomic Spectra*, (McGraw-Hill, New York, 1934)

NS-421 Statistical Physics (L2-T1-P0-CH3-CR3)

Laws of thermodynamics, free energies, phase transitions and the conditions for phase equilibrium, kinetic theory of gases, Maxwell's velocity distribution, equipartition of energy, Basic principles of statistical mechanics and its application to simple systems: Harmonic Oscillators

Phase Space, dynamics in phase space, stationary states and Liouville theorem; basic principles of equilibrium.

Concept of ensembles, micro-canonical, canonical and grand-canonical ensembles, counting and partition function, density of states, Virial theorem, derivation of thermodynamics, equation of state for ideal and real gases, Gibbs paradox.

The Partition function, generalised expression for entropy, Gibbs entropy, free energy and thermodynamic variables, the grand partition function, grand potential and thermodynamic variables, energy fluctuations in canonical ensemble, thermodynamic function, inadequacy of classical theory, derivation of van der Waals' equation from classical theory,

Quantum statistical mechanics: Density matrix and its physical significance, quantum Liouville equation, Maxwell, Fermi and Bose distributions, grand potential for identical particles, Bose-Einstein condensation, Fermi gas at low temperatures, properties of liquid Helium II, Tisza's two-fluid model, superfluidity, first and second sound, Landau theory of superfluidity.

Critical phenomena and phase transitions: Phase diagrams, order of phase transitions and order parameter, conserved and non-conserved order parameters, transfer matrix method, mean field theory, scaling theory and scaling of free energy, second-order and first-order transitions, discussion of ferroelectrics and ferromagnetism.

Textbooks:

1. Pathria, R. K., *Statistical Mechanics*, 2nd edition, (Butterworth Heinemann, 1996)
2. Huang, K., *Statistical Mechanics*, 2nd edition (Wiley, 1987)
3. Reif, F., *Statistical Physics*, (Tata McGraw-Hill, 2008)

Reference Books:

1. Landau, L. D. and Lifshitz, E. M., *Statistical Physics*, 3rd edition (Butterworth-Heinemann, 1980)
2. Stanley, H. E., *Introduction to Phase Transitions and Critical Phenomena*, (Oxford University Press, 1971)
3. Yeomans, J., *Statistical Mechanics of Phase Transitions*, (Oxford University Press, 1992)
4. Chandler, D., *Introduction to Modern Statistical Mechanics*, (Oxford University Press, 1979)

NS-402

Electronics

(L2-T1-P0-CH3-CR3)

Superposition Theorem, Mesh analysis, voltage and current sources, Thevenin's equivalent circuit, small signal resistance. Inductors and transformers: voltage and currents as complex entities, power in a reactive circuit, generalised voltage dividers.

Filters: Phasor diagrams. High pass filters, low pass filters, "Poles" and decibels per octave. Resonant circuits and active filters. Negative and positive feedbacks.

Solid state diodes and transistors, full wave bridge, centre tapped full wave rectifier, split supply, voltage multipliers, breakdown mechanism, Zener diodes, regulators and circuit application of diodes. Inductive loading and diode protection. Emitter follower as voltage

regulators. Emitter follower biasing. Diode as clipper and clamper, transistor current source. Common emitter amplifier, transconductance, junction capacitance. Brief introduction to fabrication principle.

Amplifiers and oscillators, push-pull output stages. Darlington connection. Bootstrapping. differential amplifiers. Feedback voltage regulator, power amplifier, wave form generators, Wein bridge, phase shift and RC oscillators. Astable and bistable multivibrators.

Digital Electronics, number systems, 2's complement method, Boolean algebra, logic identities and families, sequential and combinational logics.

Textbooks:

1. Horowitz, P. and Hill, W., *The Art of Electronics*, 2nd Edition (Cambridge University Press, 1995).
2. Milliman, J. & Halkias, C. C., *Integrated Electronics*, (Tata Mcgraw Hill, 1995).

Reference Books:

1. Tocci, R. J. and Widmer, N. S., *Digital System: Principles and Applications*, 8th edition, (PHI, 2000)
2. Hambley, A. R., *Electronics*, 2nd edition, (Prentice Hall, 2000).

NS-410

Nanostructures

(L2-T1-P0-CH3-CR3)

Introduction to nanoscale systems: quantum mechanical treatment, parabolic well, rectangular well, triangular well, cylindrical well and spherical well. Quantum well, quantum wire and quantum dots. Quantum size effect, size and dimensionality effects on density of states, Bohr excitons, strong and weak confinements, oscillator strength, blue-shift energy and effective mass approximation model. Semiconductor nanoparticles, nanorods, and nanotubes. Carbon nanotubes, polymeric nanofibers, nano-sponge, graphene and other layered systems.

Surface and interface properties: surface coating, coupled nanostructures, interfacial charge transfer, grain growth kinetics, surface defects; Langmuir relation; Ostwald ripening; Hall-Petch relation, grain correlated properties. Phonons in nanostructured systems; surface optic phonons; surface plasmons in metallic nanostructures, single electron effects and basics of nano-junctions.

Synthesis techniques: Top-down vs. bottom-up techniques, sol-gel method, solution growth and hydrothermal routes, mechanical milling and solid state reaction techniques, chemical and photochemical reduction routes, thermal evaporation and e-beam evaporation methods, molecular beam epitaxy.

Analytical tools: X-ray diffraction, Optical absorption and emission spectroscopy; Raman spectroscopy; scanning and transmission electron microscopy.

Green nanotechnology, challenges in nanotechnology.

Textbooks:

1. Cao, G. and Wang, Y., *Nanostructures and Nanomaterials: Synthesis, Properties, and Applications*, 2nd Edition, (World Scientific, 2011).
2. Rao, C. N. R., Thomas, P. J. and Kulkarni, G. U., *Nanocrystals: Synthesis, properties and applications*, (Springer-Verlag, 2007)

Reference Books:

1. Ariga, K., *Manipulation of Nanoscale Materials: An Introduction to Nanoarchitectonics*, (Royal Society of Chemistry, 2012).
2. Poole, Jr. C. P. and Owens F. J., *Introduction to Nanotechnology*, (Wiley, 2003).
3. Deb, P., *Kinetics of Heterogeneous Solid State Processes*, (Springer, 2013).
4. Nouailhat, A., *An Introduction to Nanosciences and Nanotechnology*, (Wiley, 2007).
5. Murty, B. S., Shankar, P., Baldev Raj, Rath, B. B., Murday, J., *Textbook of Nanoscience and nanotechnology*, (Springer, 2013).

NS-498**Laboratory- II****(L0-T0-P4-CH8-CR4)*****Physics based Experiments***

1. To measure full width at half maximum (FWHM) ESR signal of 2,2- Diphenyl-1-picrylhydrazyl sample and hence, estimate Lande' g -factor.
2. To determine the coercivity, saturation magnetization and retentivity of different given samples using hysteresis loop tracer set-up.
3. To measure the dielectric constant and loss using microwave bench setup.
4. To determine carrier concentration and Hall coefficient using Hall effect setup.
5. To draw the glow curve of an alkali halide sample exposed to X-rays or UV light and hence, estimate activation energy of the color centers.
6. To determine Planck's constant using photoelectric effect setup.
7. To study, take measurement and prepare a report on:
 - a) FT-IR spectroscopy
 - b) Raman spectroscopy
 - c) Scanning and transmission electron microscopy
 - d) Differential scanning calorimetry (DSC) and thermo-gravimetric analysis (TGA)

Chemistry based Experiments

1. To synthesize polyanniline based fibres and characterize it by optical and diffraction methods.
2. To deposit (monolayer) thin films using Langmuir-Blodgett set up and study optical properties.

Biology based Experiments

1. Isolation of plasmid DNA from bacteria
2. DNA gel electrophoresis

Semester III

NS-552

Quantum Mechanics-II

(L2-T1-P0-CH3-CR3)

Review of angular momentum, general formalism of angular momentum, addition of angular momenta and commutation relations, Clebsch-Gordon coefficients.

Time-independent perturbation theory; non-degenerate case, first-order and second-order perturbations, degenerate cases, first-order Stark effect in hydrogen atom, Time-dependent perturbation theory, Fermi golden rule.

Transition probability and WKB approximation, Ritz-variational method, scattering theory, partial wave analysis and phase shift.

Relativistic quantum mechanics, Klein-Gordon and Dirac equations, elementary idea about field quantization. Noether theorem.

Textbooks:

1. Schiff, L. S., *Quantum Mechanics*, (Tata McGraw-Hill, 2004)
2. Zettili, N., *Quantum Mechanics*, (John Wiley & Sons, 2001)

Reference Books:

1. Gasiorowicz, S., *Quantum Physics*, 3rd edition (Wiley, 2003)
2. Ghatak, A. K. and Lokanathan, S., *Quantum Mechanics: Theory and Applications*, (Springer, 2002)

NS-501

Surface Science

(L2-T1-P0-CH3-CR3)

Surface and its specificity, surface structure, Terrace-Ledge-Kink model, binding sites and diffusion, surface diffusion model, bulk electronic state, surface electronic state, Energy levels at metal interfaces, structural defects at surfaces - point defects, steps, faceting, adatoms, dislocations.

Growth and epitaxy, growth modes, interfaces, surface energy and surface tension, surface plasmonics,

Non-equilibrium growth, Langmuir-Blodgett films, self-assembled monolayers, thermodynamics and kinetics of adsorption and desorption, binding energies and activation barriers, adsorption isotherms, rate of desorption, lateral interaction.

Chemisorption, physisorption and dynamics, heterogeneous catalysis process, Atomistic mechanisms of surface diffusion – hopping mechanism, atomic exchange mechanism, tunneling mechanism.

Surface analysis: scanning probe microscopy, photoelectron spectroscopy, Auger electron spectroscopy, electron energy loss spectroscopy, low energy electron diffraction.

Textbooks:

1. Deb, P., *Kinetics of Heterogeneous Solid State Processes*, (Springer, 2013)

2. Oura, K. Lifshits, V. G. Saranin, A. A. Zotov, A. V. and Katayama M., *Surface Science: An Introduction*, 2nd edition, (Springer, 2010)
3. Desjonqueres, M.-C. and Spanjaard, D., *Concepts in Surface Physics*, 2nd edition, (Springer, 2002)

Reference Books:

1. Richardson, N. V. and Holloway, S., *Handbook of Surface Science*, Vol. 4, (Elsevier, 2014)
2. O'Connor, D. J. Sexton, B. A. and Smart R. S. C., *Surface Analysis Methods in Materials Science*, 2nd edition, (Springer, 2010)
3. Kolasinski, K. W., *Surface Science, Foundations of Catalysis and Nanoscience*, (Wiley, 2002)

NS-553 Biophysics and Nanobiotechnology (L2-T1-P0-CH3-CR3)

Cell molecular architecture: Prokaryotic and eukaryotic cells. Properties of polysaccharides, proteins, lipids and nucleic acids. Structure and function of biological membranes.

DNA technology: Gene structure and function. DNA sequencing. Gel-electrophoresis. Polymerase chain reaction (PCR).

Bioenergetics and biomechanics: Signal transduction in excitable membranes, ion transport in biomembranes, action potential, stochastic and non-stochastic ion channels

Biosynthesis of nanoparticles: Biopolymers, DNA based nanostructures, protein based nanostructures. Artificial photosynthesis.

Microscopy: Fluorescence and confocal microscopy, total internal reflectance microscopy (TIRF), scanning probe microscopy (SPM), fluorescence recovery after photo-bleaching (FRAP) and single molecule spectroscopy. Circular dichroism.

Applications: Biosensors, diagnostics and therapeutics, drug delivery, liposomes, quantum dots, bioimaging, DNA chips, surface immobilized nanobio conjugates and FRET.

Textbooks:

1. I.Niemeyer, C. M. and Mirkin, C. A., *Nanobiotechnology: Concepts, Applications and Perspectives*, (Wiley-VCH, 2004).
2. Gregoriadis, G., *Liposomes in Biological systems*, (Wiley-Blackwell, 1980)
3. Cotteril, R., *Biophysics: An introduction*, 1st edition (Wiley, 2009).
4. Nelson, P., *Biological Physics: Energy, Information and Life*, (Freeman, 2007).

Reference Books:

1. S. Dumitriu (Editor), *Polymeric biomaterial*, (Marcel Dekker, 1989).
2. Lodish, H., Berk, A., Matsudaira, P., Zipursky, S. L., Baltimore, D., Darnell, J., *Molecular Cell Biology*, 5th Edition, (Macmillan Higher Education, 2004).
3. Calladine and Drew, A. P., *Understanding DNA*, (Academic Press, 2004)
4. Yagle, P., *The membranes of cells*, (Academic press, 1993)
5. Glaser, R., *Biophysics*, 1st edition (Springer, 2001)
6. Brown, T. A., *Genomes*, 2nd edition, (Wiley-Liss, 2002).

7. Donbrow, M., (Editor), *Microcapsules and Nanoparticles in Medicine and Pharmacy*, (CRC Press, 1992).
8. Grigorenko, E. V., *DNA Arrays: Technologies and experimental strategies*, (CRC Press, 2002).

NS-554 Computation and Modeling Techniques (L0-T1-P3-CH7-CR4)

Numerical Analysis: Solution of non-linear equations - Newton's method, method of false position (regular falsi); solution of a system of linear equations, Gaussian elimination, iterative methods (Jacobi and Gauss-Seidel methods); Interpolation - Newton's interpolation formula; numerical differentiation and integration - Simpson's rule, trapezoidal rule, quadrature formula; numerical solution of ordinary differential equations Euler's method, Runge-Kutta method; fitting of curves - principle of least squares.

Simulation: A system and its model; the basic nature of simulation; the simulation of continuous and discrete systems - suitable examples; stochastic simulation - generation of random numbers with different probability distributions; simulation in physical and realistic situations.

Textbooks:

1. Mathews, J. H., *Numerical Methods for Mathematics, Science and Engineering*, (Prentice Hall, 1997)
2. Narsingh Deo, *System Simulation with Digital Computers*, (Prentice Hall, 1979)

Reference Books:

1. Yashwant Kanetkar, *Let us C*, (BPB Publications, 2012)
2. Gottfried, B .S., *Schaum's outline of theory and problems of programming with C*, (McGraw-Hill Professional, 1996)

Computational Laboratory -

- a. To find mean, variance, standard deviation, moments etc. for a given set of data (about 50 entries)
- b. To fit a linear curve for a given set of data
- c. To perform a polynomial fit for a given set of data
- d. To find the roots of a quadratic equation
- e. Fourier Analysis of a square
- f. To generate random numbers between 1 and 100.
- g. To perform numerical integration of 1-D function using Simpson and Weddle rules
- h. To find determinant of a matrix, its eigenvalues and eigen vectors
- i. To simulate phenomenon of nuclear radioactivity using Monte Carlo technique.

Semester IV

NS-559 Nanophotonics**(L2-T1-P0-CH3-CR3)**

Non-linear photonics: Non linear optical media, Second order and third order non-linear optics, three wave mixing, frequency and phase matching, self phase modulation, self focusing, spatial soliton, Raman amplification, Brillouin scattering.

Electro-optic effects: optical Kerr effect, Pockel effect, Magneto-optic effects, Faraday effect, Magneto-optic Kerr effect (MOKE), Surface enhanced MOKE in nanoscale structures.

Surface plasmons: Optical properties of noble metals, Drude- Sommerfeld theory, surface plasmon polariton at plane interface, properties of surface plasmon polaritons, excitation of surface plasmon polaritons, surface plasmon sensors, surface enhanced Raman spectroscopy (SERS), surface plasmon in nano-optics.

Photonic crystals: Electromagnetic in mixed dielectric media, symmetries and solid state electromagnetism, 1D , 2D and 3D photonic crystal, Photonic crystal fiber, Application of photonic crystals.

Textbooks:

1. Simmons, J. H., *Optical Materials*, (Academic Press, 2006).
2. Woggon, U., *Optical properties of Semiconductors*, (Springer-Verlag, 2000).
3. Boyd, R. W., *Non-Linear optics*, 2nd edition, (Elsevier, 2006),
4. Fukuda, M., *Optical Semiconductor Devices*, (John Wiley & Sons, 2005)
5. Maier, S. A., *Plasmonics: Fundamentals and Applications*, illustrated 2nd edition, (Springer, 2007)

Reference Books:

1. Chuang S. L., *Physics of Photonic devices*, (Wiley Series, 2009).
2. Shen, Y. R., *Principle of Non-Linear Optics*, (Wiley India, 2013)
3. Silvestri, L., Di Bartolo, B. and Collins, J., *Nano-Optics for Enhancing Light-Matter Interactions on a Molecular Scale: Plasmonics, Photonic Materials and Sub-Wavelength Resolution*, (Springer, 2012)
4. Joannopoulos, J. D., Meade, R. D. and Winn, J., *Photonic Crystal: Molding the flow of Light*, (Princeton Univ. Press, 2008).
5. Novotny, L. and Hecht, B., *Principles of Nano-optics*, (Cambridge, 2009).

NS-558 Nanomagnetism**(L2-T1-P0-CH3-CR3)**

Classical and Quantum Magnetism, Magnetism of Atoms, Magnetic Ordering, Micromagnetism, Domain and Hysteresis, Paramagnetism, Ferromagnetism, Anti-ferromagnetism, Ferrimagnetism, Magnons, Exchange Interactions.

Magnetic Anisotropy, Order and Broken Symmetry, Consequences of Broken Symmetry, Landau Theory of Ferromagnetism, Heisenberg and Ising model, Domain and Domain Walls, Equation of Motion for Domain Walls.

Nanoscale Magnetism, Superparamagnetism, Stoner-Wohlfarth model, Interparticle Interaction.

Magnetoresistance - Magnetoresistance of Ferromagnets, Anisotropic Magnetoresistance, Giant Magnetoresistance, Spintronics, Molecular magnetism.

Nuclear Magnetic Resonance, Magnetic Resonance Imaging.

Neutron Diffraction, SQUID.

Textbooks:

1. Coey, J. M. D., *Magnetism and Magnetic Materials*, (Cambridge University Press, 2009).
2. Cullity, B. D. and Graham C. D., *Introduction to Magnetic Materials*, 2nd Edition, (Wiley-IEEE Press, 2008)

Reference Books:

1. Peddie, W., *Molecular Magnetism*, (Nabu Press, 2011).
2. Spaldin, N. A., *Magnetic Materials: Fundamentals and Applications*, 2nd Edition, (Cambridge University Press, 2010).

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