

Syllabus as per NEP 2020

PG Program



Department of Physics

Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur

**EFFECTIVE FROM THE SESSION
2022-2023**

PG PROGRAM
DEPARTMENT OF PHYSICS
(SESSION: 2022 – 2023)

In accordance with the recommendations of NEP-2020 and the Uttar Pradesh Government, the Program and course structures /syllabi format of M.Sc. Physics are modified. As per these recommendations, a student admitted to PG program will have to opt in each semester (i) four major courses (each of 4 credits) (ii) one practical course (04 credits), and (iii) One Project work (04 credits). In the first or in second semester students, studying in Department of Physics, have to select one minor elective course (04 credits) from the faculty other than the faculty of Science.

Two year PG program consists of four semesters with a minimum of 100 credits. If a student completed one year (Semester I & II) with minimum of 52 Credits, he will be awarded the degree of Bachelor of Science (Research). The students completing the two years (Semesters I-IV) course with minimum of 52+48 credits will be awarded Master of Science (Physics).

The minor elective course (04 credits) provided by the Department of Physics will be offered to the students studying in faculties other than the faculty of Science.

Programme Specific Outcomes:

- To develop understanding of basic concepts of Physics and appreciate how simple fundamental laws govern diverse natural phenomenon.
- To advance knowledge of the latest progress and applications in Physical Science.
- To inculcate logical thinking and skills for deductive analysis.
- To learn experimental skills and analysis tools.
- To encourage for research and higher studies in Physics and related fields.
- To prepare for Physics competitive exams e.g. CSIR-NET, GATE, JEST etc.
- To prepare foundations that can make good Physics teachers.
- To become lifelong learners and contribute to society in any career.

Course Structure

PG Program in Physics (NEP 2020)

Semester I:

COURSE NO.	NAME OF THE COURSE	CREDIT	REMARK
PHY-501	Mathematical Physics	4+0	Major
PHY-502	Classical Mechanics	4+0	Major
PHY-503	Quantum Mechanics	4+0	Major
PHY-504	Electronics	4+0	Major
PHY-505 OR PHY-506	Physics Practical -Electronics Physics Practical -Optics	0+4	Major
PHY-507	Research Project-I	4*	Major
TOTAL CREDITS		24	

Semester II:

COURSE NO.	NAME OF THE COURSE	CREDIT	REMARK
PHY-508	Thermodynamics and Statistical Physics	4+0	Major
PHY-509	Electromagnetic Theory and Plasma Physics	4+0	Major
PHY-510	Solid State Physics	4+0	Major
PHY-511 OR PHY-512	Group Theory and Molecular Spectra OR Experimental Techniques and Computational Methods	4+0	Major
PHY-505 OR PHY-506	Physics Practical -Electronics Physics Practical -Optics	0+4	Major
PHY-513	Research Project-II	4*	Major
TOTAL CREDITS		24	

Minor Elective Course:

COURSE NO.	NAME OF THE COURSE	CREDIT	REMARK
PHY-546 OR PHY-547	Elementary Atmospheric Physics OR Frontiers of Physics	4+0	Minor

Semester III:

COURSE NO.	NAME OF THE COURSE	CREDITS	REMARK
PHY-514	Numerical Methods and Programming	4+0	Major
PHY-515	Electrodynamics	4+0	Major
PHY-516	Advanced Quantum Mechanics	4+0	Major
PHY-517 OR PHY-518 OR PHY-519 OR PHY-520 OR PHY-521 OR PHY-522	Astrophysics-I Biophysics-I Electronics-I Solid State Physics-I Spectroscopy and LASERs-I X-Rays-I	4+0	Major (Specialization)
PHY-523 OR PHY-524 OR PHY-525 OR PHY-526 OR PHY-527 OR PHY-528	Physics Practical-Astrophysics-I Physics Practical-Biophysics-I Physics Practical-Electronics-I Physics Practical-Solid State Physics-I Physics Practical- Spectroscopy and Lasers-I Physics Practical-X-Rays-I	0+4	Major
PHY-529	Masters Dissertation Project-I	4*	Major
TOTAL CREDITS		24	

Semester IV:

COURSE NO.	NAME OF THE COURSE	CREDITS	REMARK
PHY-530	Nuclear and Particle Physics	4+0	Major
PHY-531	Lasers & Modern Optics	4+0	Major
PHY-532	Condensed Matter Physics	4+0	Major
PHY-533 OR PHY-534 OR PHY-535 OR PHY-536 OR PHY-537 OR PHY-538	Astrophysics-II Biophysics-II Electronics-II Solid State Physics-II Spectroscopy and Lasers-II X-Rays-II	4+0	Major (Specialization)
PHY-539 OR PHY-540 OR PHY-541 OR PHY-542 OR PHY-543 OR PHY-544	Physics Practical-Astrophysics-II Physics Practical-Biophysics-II Physics Practical-Electronics-II Physics Practical-Solid State Physics-II Physics Practical- Spectroscopy and Lasers- II Physics Practical-X-Rays-II	0+4	Major
PHY-545	Masters Dissertation Project – II	4*	
TOTAL CREDITS		24	

*** Evaluation will be done internally at Department level on the basis of presentation and viva-voce in accordance with procedure laid down in BoS.**

PG Syllabus Description Semester I

PHY 501: Mathematical Physics: Credit 4+0

Course Objectives: Understanding mathematical functions and solution methods useful in various branches of Physics.

Unit – I

Special Functions: Second order linear differential equations; Solution by series expansion; Legendre, Bessel, Hermite and Laguerre differential equations, their solutions and properties, Spherical Harmonics.

Unit – II

Fourier Transform: Dirac Delta function, Fourier Transform, Sine and Cosine transform, Linearity, Change of Scale, Translation, Modulation, simple applications.

Green Function: Green's function as a technique to solve linear ordinary differential equations, Homogeneous and Inhomogeneous boundary conditions, Solution of Poisson equation using Green's function technique, Symmetry property.

Unit – III

Complex Variables I: General function of complex variable, Cauchy-Riemann differential equation and analyticity, conformal mapping (translation, rotation, inversion), Cauchy's integral formula, Taylor's and Laurent's series, singularity poles.

Unit – IV

Complex Variables II: Residue theorem. Evaluation of definite integrals, around (i) unit circle and (ii) infinite semi-circle; using Jordan's lemma with poles lying on real axis, and of integrals involving multiple valued function-branch point.

References:

1. Mathematical Methods for Physicists by G. Arfken, H. Weber and F.E. Harris (Elsevier)
2. Mathematics for Physicist by P. Dennery and A. Krzywicki (Dover Publication)
3. Special Functions and their Applications by N.N. Lebedev (Dover Publication)
4. Mathematical Methods for Physics and Engineering by K.F. Riley, M.P. Hobson and S.J. Bence (Cambridge University Press)
5. Mathematical Physics by B. S. Rajput (Pagati Prakashan)
6. Complex Variables and Applications by J.W. Brown and R. V. Churchill (McGraw-Hill)

Course Outcomes:

- The students will understand various functions and solutions to differential equations.
- The foundation for understanding of Classical and Quantum Mechanics will be laid.
- The techniques learnt will be useful in different branches of Physics.

PHY-502: Classical Mechanics: Credit 4+0

Course Objectives: Understanding basic methods of mechanics and use of Lagrangian and Hamiltonian approach.

Unit - I

Vectors: Curvilinear Coordinates, Gradient, Divergence and Curl, Laplace equation in spherical polar and cylindrical polar coordinates and their solution, Green's theorem, Gauss and Stokes Theorems.

Tensors: Covariant and Contravariant vectors, Tensors – Addition, Multiplication, Contraction, Symmetry properties; Tensor density, Pseudo-tensors.

Unit-II

Mechanics of a system of particles: Generalized coordinates and Constraints, Generalized coordinates, D' Alembert's principle, Lagrange's Equation. Hamilton's principle, Least action principle, Lagrange's equations, symmetry properties and Noether's theorem, Lagrangian formulation for elementary mechanical systems - free particle, simple and double pendulum.

Unit-III

Two Body Problem: Reduction to one-body problem, reduced mass, Virial Theorem, planetary orbits.

Scattering: Collision between particles, disintegration of particles, elastic collisions, scattering, Rutherford's formula.

Small oscillations: Damped and Forced oscillations, coupled vibrations.

Unit-IV

Hamiltonian Formulation: Hamilton equations, canonical transformations, Poisson's bracket, Symplectic approach to canonical transformations; Hamilton Principle function, Hamilton-Jacobi equation, Harmonic Oscillator Problem, Hamilton characteristic Function, separation of variables, Central Force problem.

References:

1. Vector Analysis and Introductory Tensor Analysis by M.R. Spiegel (Schaum Series)
2. Matrices and Tensors in Physics by A.W. Joshi (New Age)
3. Classical Mechanics by H. Goldstein (Narosa, New Delhi)
4. Classical Mechanics by K.C. Gupta (Wiley Eastern)
5. Classical Mechanics by L.D. Landau (Elsevier)
6. Classical Mechanics by N.C. Rana and P.S. Joag (Tata-McGraw-Hill)

Course Outcomes:

- The students will understand dynamics of particles and conservation laws. The understanding of different mechanical problems and their solutions will be developed.

PHY-503: Quantum Mechanics: Credit 4+0

Course Objectives: Understanding concepts of quantum mechanics and solving operator equations for different quantum problems.

Unit-I

Wave Mechanical formulation: Schrodinger wave equation, Hermitian operators and observables, Discrete and continuous spectrum, Dirac delta function, Commuting observables and related algebra, Pure and mixture states; Simple applications: potential well, barrier potential, tunnel effect, unbound states: reflection and transmission of waves.

Unit - II

Identity of Particles: Distinguishability of identical particles, exchange degeneracy and operator, construction of symmetric and antisymmetric wave functions, Pauli's exclusion principle and Slater's determinant, Electron spin hypothesis, spin matrices and eigen value equations, symmetric and antisymmetric wave functions for hydrogen molecule.

Unit - III

Matrix formulation: Concept of Hilbert Space, Dirac's bra and ket notations, Orthonormality and completeness relations (discrete and continuous), linear and real operators, eigen value equations and related theorems, projection operators and measurement, application to Harmonic Oscillator, Equivalence of wave and matrix mechanics.

Unit - IV

Theory of Angular momentum: Orbital, spin and total angular momentum operators: eigen value equations and matrix representations, Ladder operators, commutation relations, Addition of angular momenta, Clebsch-Gordon coefficients.

References:

1. Quantum Mechanics, Vol. I & II by Albert Messiah (Dover Publication)
2. The Principles of Quantum Mechanics by P.A.M. Dirac (Oxford University Press)
3. Quantum Mechanics by L.I. Schiff (Tata-McGraw-Hill)
4. Modern Quantum Mechanics by J.J. Sakurai (Addison Wesley)
5. Introduction to Quantum Mechanics by D.J. Griffiths (Pearson Education)
6. Quantum Mechanics by C. Cohen-Tannoudji, B. Diu and F. Laloe (Wiley VCH)
7. Quantum Mechanics by B. K. Agarwal and Hari Prakash (Prentice-Hall, India)

Course Outcomes:

- The students will understand wave mechanical formulation of quantum particles and various rules arising out of it.
- The understanding of different formulations of quantum mechanics laying foundations for the study of molecules, atoms and fundamental particles

PHY-504: Electronics: Credit 4+0

Course Objectives: Understanding functions of electronic devices and circuit logic.

Unit - I

Power Electronics: SCR: Basic structure, I-V characteristics and two-transistor model of SCR, SCR controlled half and full wave rectifier circuit and their analysis. UJT, equivalent circuit, I-V characteristics, Saw tooth wave generation. Elements of SMPS.

Unit - II

Operational Amplifier: IC-741 -Block diagram, operation, Characteristics of op-amp; inverting and non-inverting inputs: Input offset current and Input offset voltage, differential amplifier, CMRR, Slew rate and power band width, op-amp as an amplifier. Application of Op-amp: summer, integrator and differentiator. Timer: IC-555 -Block diagram, Astable and Monostable operations, applications of IC-555 - VCO.

Unit - III

Boolean Algebra and Gates: Boolean algebra, composite function and their algebraic simplification, De-Morgan's theorem, duality in Boolean algebra, Universality of NAND and NOR gates. SOP and POS forms, karnaugh map, design of logic circuits, X-OR gate and its applications, half adder and full adder, parallel adder, look ahead carry.

Unit - IV

Elements of Logic Families: Transistor as a switch, FAN IN, FAN OUT, Noise Immunity, propagation delay, RTL, DTL, TTL logic, Sourcing and Sinking logic, TTL loading and Fan out, ECL logic.

References:

1. Switch Mode Power Conversion by K. Kit Sum (Marcel Dekker).
2. Power Electronics by P.C. Sen (Tata Mc Graw-Hill)
3. Pulse, Digital and Switching Wave Forms by J. Milman and H. Taub (McGraw-Hill)
4. Op-amp and Linear Integrated Circuits by R.A. Gayakwad (Prentice-Hall India)
5. Integrated Circuits by J. Millman and C.C. Halkias (Tata-McGraw-Hill)
6. Digital Principle and Application by A.P. Malvino and D.P. Leach (McGraw-Hill)
7. Modern Digital Electronics by R.P. Jain (Tata McGraw-Hill)

Course Outcomes:

- The students will understand electronic circuits and control using various devices.
- The students will understand simple logic and control via logic circuits.

*** The following two courses PHY-505 and PHY-506 are mandatory. One course will be allotted in the I semester and the other in II semester.**

PHY-505: Physics Practical-Electronics: Credit 0+4

Course Objectives: The student will handle instruments, take readings and analyze the results, to understand various concepts and applications.

LIST OF EXPERIMENTS

Students will be required to perform at least five experiments from each course. They will have to maintain record books of experiments done.

1. Study of regulator circuits
2. Study of switch mode power supply (SMPS)
3. Study of characteristic of SCR and controlled rectification by SCR.
4. Study of RC coupled amplifier
5. Study of emitter follower
6. Study of phase shift oscillator
7. Study of multivibrator: Use of 555
8. Study of saw tooth wave generation by UJT
9. Study of characteristics of operational amplifier
10. Study of TTL gates
11. Study of combinational logic circuits
12. Study of super heterodyne receiver
13. Study of linear and square wave detector
14. Microwave measurement: Mode analysis and standing wave ratio

Course Outcomes:

- Learning circuit fundamentals and making connections to study properties of electronic devices.
- Learn to present observations, results and analysis in suitable and presentable form.

PHY-506: Physics Practical- Optics: Credit 0+4

Course Objectives: The student will handle instruments, take readings and analyze the results, to understand various concepts and applications.

LIST OF EXPERIMENTS

Students will be required to perform at least five experiments from each course. They will have to maintain record books of experiments done.

1. Use of constant deviation spectrograph
2. Use of Fabry-Perot interferometer
3. Use of concave grating
4. He-Ne Laser
5. e/m by Zeeman effect
6. EPR of free radicals
7. Programming on PC
8. Velocity of ultrasonic wave
9. Hall effect
10. Magnetic Susceptibility
11. Measurement of dipole moment
12. Use of scintillation counter
13. Determination of Dielectric Constant
14. Double slit/Triple slit/ Four slit Wedge shape

Course Outcomes:

- Hands on experience with optical instruments and understanding concepts of physical optics.
- Learn to present observations, results and analysis in suitable and presentable form.

PHY-507: Research Project - I: Credit 4*

Course Objective: The primary goal of this course is to open the students to visualize and learn new techniques. The assigned project work could be related to the experiments available, theoretical concepts and development. The candidate shall submit a brief report and present seminar.

Course Outcomes: Student will learn presentation skills including making power point presentations etc.

Semester-II

PHY 508: Thermodynamics and Statistical Physics: Credit 4+0

Course Objectives: Understanding laws of thermodynamics and microscopic statistical description.

Unit – I

Second law of thermodynamics, Entropy and Probability, Thermodynamic Potentials, Thermodynamic Equilibrium, Third law of thermodynamics, First and Second order phase transitions: Clausius - Clapeyron and Ehrenfest's equations; Chemical potential and phase equilibria, Gibb's phase rule.

Unit – II

Thermodynamic properties of liquid Helium II, The lambda - transition, London's explanation, Quantum liquid, Tisza two fluid model, Landau spectrum, concept of second sound.

Conditions for Equilibrium, Entropy of an Ideal Boltzmann gas, Gibb's paradox, Sackur - Tetrode equation.

Unit – III

Canonical and Grand Canonical Ensembles, Entropy of a system in contact with heat reservoir, Ideal gas in canonical ensemble, Maxwell velocity distribution, Grand canonical ensemble, Thermodynamics of photons, Translational, Rotational and Vibrational partition functions of a molecule and their applications.

Unit – IV

Thermodynamical properties, Black body radiation, Bose - Einstein Condensation, Ideal Fermi - Dirac gas, Fermi temperature, applications of degeneracy to free electrons in metals, Magnetic susceptibility, White dwarfs and Chandrashekhar limit.

References:

1. A Treatise on Heat by M.N. Saha and B.N. Srivastava (Indian Press Limited, Allahabad)
2. Heat and Thermodynamics by M.W. Zemansky and R.H. Dittman (McGraw Hill)
3. Fundamentals of Statistical and Thermal Physics by F. Reif (McGraw-Hill)
4. Statistical Mechanics by K. Huang (John Wiley & Sons)
5. Statistical Mechanics by R.K. Pathria (Elsevier)
6. Statistical Mechanics and Properties of Matter by E.S.R. Gopal (Macmillan Ltd., Delhi)
7. Statistical Mechanics by B. K. Agarwal and M. Eisner (Wiley Eastern)

Course Outcomes:

- The students will understand laws of thermodynamics and relation between macroscopic and microscopic properties.
- The students will be able to apply the concepts in different states of matter.

PHY 509: Electromagnetic Theory and Plasma Physics: Credit 4+0

Course Objectives: Understanding Physics of Electromagnetic waves and plasma state.

Unit – I

Maxwell Equations: Microscopic and Macroscopic fields, Macroscopic Maxwell equations, Fields **D** and **H**, Dielectric tensor, Principal dielectric axes.

Potential and Gauges: Scalar and vector potentials, Gauge transformation, Lorentz gauge and Transverse gauge, Maxwell equations in terms of electromagnetic potentials.

Unit - II

Propagation of Electromagnetic Waves: Propagation of electromagnetic waves in free space, conducting and non-conducting medium, skin depth, Boundary conditions on EM Fields, Reflection and refraction at a plane interface between dielectrics.

Polarisation of EM Waves: Fresnel's Formula, Normal- and anomalous- Dispersion, metallic reflection. EM Wave in bound media: rectangular and circular wave guides, TE, TM and TEM Modes, Cut-off frequency and Wavelength.

Unit – III

Plasma State: Plasma state of matter, Motion of charge particles in uniform E & B fields, non-uniform fields, drifting motion, electrostatic and magnetostatic lenses; Time varying E & B fields, Adiabatic invariants, Plasma confinements (Pinch effect, Mirror confinement, Van Allen Belts), Elementary idea of fusion technology.

Unit – IV

Hydrodynamics of Plasma: Hydrodynamical description, Equation of magneto hydrodynamics, High frequency plasma oscillations, Short wavelength limit and Debye-screening distance.

Wave Phenomenon in Magneto-Plasma: Electromagnetic waves perpendicular to B_0 , phase velocity, Polarization, Cut-off and resonances, Electromagnetic waves parallel to B_0 , Alfvén waves.

References:

1. Introduction to Electrodynamics by D.J. Griffiths (Prentice - Hall, New Delhi)
2. The Classical theory of Fields by L.D. Landau and E.M. Lifshitz (Elsevier)
3. Classical Electrodynamics by J.D. Jackson (Wiley Eastern)
4. Introduction to Plasma Physics by F.F. Chen (Plenum Press, New York)
5. Plasma Physics by S.N. Sen (Pragati Prakashan)

Course Outcomes:

- The students will understand nature of Electric and Magnetic fields, Electromagnetic waves and plasma state.
- The students will be able to apply the concepts in various branches of Physics.

PHY 510: Solid State Physics: Credit 4+0

Course Objectives: Understanding the physics related to matter in solid state.

Unit - I

Crystal Structure: Ionic, covalent, metallic and hydrogen bonding, space lattice and basis ; Types of lattice, Miller indices, crystal structures of NaCl, CsCl, ZnS, graphite and diamond; Reciprocal lattice and Brillouin Zones; Basic idea of crystal defects and dislocations.

Unit – II

Band Theory of Solids: Sommerfield model, Density of states, Fermi and mean energies at zero and finite temperatures; Origin of energy bands; Bloch Theorem; Kronig Penny model, Electron dynamics in crystalline lattice; Tight binding approximation.

Unit - III

Thermal Properties: Lattice vibrations of mono and diatomic chains, Quantization of lattice vibration, Phonon; Infrared absorption; Einstein and Debye theories of specific heat; Thermal conductivity; Anharmonicity and Thermal expansion.

Unit - IV

Optical Properties: Optical reflectance, Kramers-Kronig relations; Conductivity and dielectric function of electron gas; Basic theory of luminescence, phosphorescence, thermoluminescence, electroluminescence and photo-conductivity; Excitons in ionic and molecular crystals, Electron-hole drops (EHD) and colour centres.

References:

1. Solid state Physics by A.J. Dekkar (McMillan Publishers)
2. Introduction to Solid State Physics by C. Kittel (Wiley Eastern)
3. Elementary Solid State Physics by M. Ali Omar (Pearson Education)
4. Solid State Physics, N.W. Ashcroft and N.D. Mermin, (Harcourt Asia Limited)
5. Principles of the Theory of Solids by J.M. Ziman (Cambridge University Press)
6. Solid State Physics by S.O. Pillai (New Age Publishers)

Course Outcomes:

- The students will understand crystal structure and energy concepts.
- Learn different properties of solids and their relation to crystal structure and defects.

PHY 511: Group Theory and Molecular Spectra: Credit 4+0

Course Objectives: Understanding radiations due to transitions in molecules and symmetry considerations for them.

Unit – I

Rotation and Vibration Spectra: IR and Raman spectra of rigid rotator and harmonic oscillator, IR and Raman spectra of non-rigid rotator, anharmonic oscillator and vibrating rotator, Intensities in rotation - vibration spectra, Isotope effects in rotation and vibration spectra.

Unit – II

Electronic Spectra: Electronic energy and total energy, vibration structure of electronic transitions, progressions and sequences, rotational structure of electronic bands, band head formation and band origin. Intensity distribution in vibrational structure, Frank-Condon principle and its quantum mechanical formulation, intensity alternation in rotational lines.

Units – III

Group Theory: Symmetry elements and symmetry operations, Point group and their representation, Mathematical group, Matrix representation, Orthogonality theorem (statements and interpretation only), Reducible and irreducible representations, Direct product group.

Unit – IV

Vibrational and Raman Spectra: Normal modes, symmetry characterization of electronic states and vibrational modes of polyatomic molecules, character tables (C_{2v} , D_{3h} and D_{6h}) and their applications to selection rules of IR and Raman spectra, application to H_2O and CO_2 molecules.

References:

1. Molecular Spectra and Molecular Structure by G. Herzberg (Dover Publication).
2. Fundamentals of Spectroscopy by C.N. Banwell and E.M. McCash (Tata-McGraw-Hill)
3. Introduction to Molecular Spectroscopy by G.M. Barrow (McGraw-Hill)
4. Modern Spectroscopy by M.J. Hollas (Wiley Inter Science)
5. Elements of Group theory for Physicists by A.W. Joshi (Wiley Eastern)
6. Chemical Applications of Group Theory by F.A. Cotton (Wiley Eastern)

Course Outcomes:

- The students will understand various electromagnetic transitions in molecules.
- Finding selection rules using symmetry and group considerations.
- The students will be able to apply the concepts in various branches of Physics.

PHY-512: Experimental Techniques and Computational Methods: Credit 4+0

Course Objectives: Students will get exposure of working principal and theories of various spectroscopic and structural characterization techniques useful in characterizing materials and to introduce some computational approaches being used in molecular modelling.

Unit I-Spectroscopic Techniques:

Microstructural characterization using X-ray Diffraction and neutron diffraction spectroscopy, UV and Visible absorption spectroscopy, IR and Raman spectroscopy, Basics of nuclear magnetic resonance (NMR) and electron spin resonance (ESR) spectroscopy.

Unit II-Microscopic Characterization Techniques:

Basics and applications of Scanning electron microscopy (SEM), Scanning tunnelling microscopy (STM), Atomic Force Microscopy (AFM), Focussed ion beam (FIB) system, Transmission Electron Microscopy (TEM).

Unit - III : Basics of Molecular Modelling

Introduction to coordinate systems, potential energy surfaces, model building and computer simulation; introduction to quantum mechanics – postulates –Schrodinger wave equation – operators – eigen function – eigen values – expectation values – hydrogen molecule – Born-Oppenheimer approximation.

Unit IV: Molecular mechanics, Energy minimization and MD Simulation:

Empirical force field models – Bond stretching – angle bending – torsional term –nonbonding interactions – thermodynamics properties using a force field; boundary conditions, searching configuration space and generating ensemble; Derived and non-derive denegy minimization methods – steepest descent and conjugate gradient methods; Molecular dynamics simulation – integration algorithms.

Reference Books:

1. Spectroscopy Volume 1, 2 and 3: B.P. Straughan and S. Walker.
2. Modern Spectroscopy: J.M. Hollas.
3. Transmission Electron Microscopy of Metals: Gareth Thomas
4. Elements of X-ray Diffraction: Bernard Dennis Cullity.
5. Atomic Force Microscopy/Scanning Tunneling Microscopy: M.T. Bray, Samuel H. Cohen and Marcia, L. Lightbody.
6. A. R. Leach - Molecular Modelling Principles and Application, 2nd edition, Longman Publications, 1996.
7. F. Jensen – Introduction to Computational Chemistry, 2nd edition, John Wiley & Sons Ltd.,2007.
8. T. K. Attwood, D. J. parry-Smith, Introduction to Bioinformatics, Pearson Education, 1st Edition, 11th Reprint 2005

Course Outcome:

- Learning the basics of various spectroscopic and microscopic techniques useful for material characterization.
- This course may be useful for students from other departments as well.
- Students will learn basic theories of computer modelling and molecular dynamics simulation

PHY-513: Research Project - II: Credit 4*

Course Objective: The primary goal of this course is to open the students to visualize and learn new techniques. The assigned project work could be related to the experiments available, theoretical concepts and development. The candidate shall submit a brief report and present seminar.

Course Outcomes: Student will learn presentation skills including making power point presentations etc.

Semester-III

PHY 514: Numerical Methods and Programming: Credit 4+0

Course Objectives: Learn elements of computer programming and understand computational methods applicable in various branches of Physics.

Unit - I

Numerical Analysis I: Interpolation: methods of interpolation, least square curve fitting, Methods of equal intervals, unequal intervals, Central Differences. Inverse interpolation: Iteration of successive approximation, exchange of dependent and independent variables and reversion of series. Numerical differentiation: Method based on interpolation, on finite differences. operator and on undetermined coefficients.

Unit – II

Numerical Analysis II: Numerical integration: Simpson's one-third and one-eighth rule, Euler-Maclaurin formula, Quadrature formulae, Numerical Solution to ordinary differential equation by Euler's and Runge-Kutta methods, Solution of algebraic and transcendental equations: Convergence, Newton-Raphson method, Iterative methods.

Unit - III

Fortran: Flow Charts, Integer and Floating point Arithmetic, Expression, Built in functions, Executable and Non- Executable statements, Assignments, Control and Input and Output Statements, Looping, Function and Subroutines, Operation with files.

Unit - IV

Application to Numerical Analysis related to Unit II.

References:

1. Introductory Methods of Numerical Analysis by S.S. Sastry (Prentice-Hall India)
2. Numerical Methods by E. Balguruswamy (Tata McGraw-Hill)
3. Fortran 77 and application to Numerical Analysis by C. Xavier (New Age Publishers)
4. Numerical Recipes for FORTRAN by W. Press et al. (Cambridge University Press)
5. Computer Programming in FORTRAN by V. Rajaramanna (Prentice-Hall India)

Course Outcomes:

- The students will understand various numerical techniques.
- Will be able to use or write computer programs for solving mathematical equations.

PHY 515: Electrodynamics: Credit 4+0

Course Objectives: Understanding behaviour of electromagnetic fields in relativistic and quantum regimes.

Unit-I

Four Dimensional Formulation: Postulates of special theory of relativity, Minkowski Space, Lorentz transformation, Intervals, Light cone, Proper time, Four Vectors, Doppler Effect (Transverse and Longitudinal) and Aberration, Relativistic Mechanics: Lagrangian formulation, Principle of least action, Four-momentum vector of a free particle, Hamiltonian, Equation of motion.

Unit – II

Electromagnetic Field Equations: Four Potential Four dimensional formulation: Action of a charged particle, Generalised Momentum and Hamiltonian, Equation of motion, Electromagnetic field tensor, Transformation properties of electric and magnetic fields, Invariants of Electromagnetic field, Four dimensional formulation of first and second pair of Maxwell equations, Equation of continuity.

Unit – III

The Field of Moving Charges: Retarded potentials, Lienard-Wiechert potentials, Field due to system of charges at large distances, Dipole radiation, Quadrupole and magnetic dipole radiation; Field at near distances, Radiation from a rapidly moving charge, Synchrotron radiation (magnetic bremsstrahlung), Radiation damping.

Unit – IV

Field Quantization: Lagrangian and Hamiltonian formalism for relativistic field, canonical commutation relations and quantization of Klein-Gordon field, Complex scalar field; Normal ordering, EM field as non-interacting harmonic oscillators, Quantization of radiation field, Algebra of annihilation and creation operators and their representations.

References:

1. The Classical theory of Fields by L.D. Landau and E.M. Lifshitz (Elsevier)
2. Classical Electrodynamics by J.D. Jackson (Wiley Eastern)
3. Classical Electricity and Magnetism by W. Panofsky and M. Phillips (Dover Publication)
4. Quantum Electrodynamics by F. Mandl & G. Shaw (John Wiley and Sons)
5. A First Book of Quantum Field Theory by A. Lahiri & P.B. Pal (Narosa, New Delhi)

Course Outcomes:

- The students will understand relativistic electromagnetic field equations and the concept of field quantization.
- The students will get familiar with concepts useful for research in many areas of Physics.

PHY 516: Advanced Quantum Mechanics: Credit 4+0

Course Objectives: Understanding advanced concepts of quantum mechanics and its application in understanding molecular structure.

Unit – I

Approximate methods: Time independent perturbation theory and anharmonic oscillator, Variational method and Helium atom, Time dependant perturbation theory and transition probability (Fermi-Golden Rule), WKB method and alpha decay.

Unit - II

Molecular Structure: H_2^+ ion, Born-Oppenheimer approximation and its application, H_2 molecule. Heitler-London theory, Valence bond theory of diatomic molecules, exchange energy; Simple valence bond treatment of H_2O and C_6H_6 molecules; LCAO approximation, application to H_2 and other molecules, hybridization, Huckel approximation and its application to butadiene and benzene molecules.

Unit-III

Relativistic quantum mechanics: Klein-Gordon equation, Plane wave solution and Physical interpretation, Inadequacy of Klein-Gordon equation; Dirac equation, α and β matrices and related algebra, Representation and arbitrariness of α and β , Probabilistic interpretation.

Unit – IV

Covariance of Dirac equation: Covariant form of Dirac equation, Dirac(γ) matrices, Representation and algebra, Linearly independent set of composite γ - matrices; Infinitesimal and Finite proper Lorentz transformation, Proof of covariance, Plane wave solution and negative energy states; Two component Pauli spin theory, Non relativistic correspondence.

References:

1. Quantum Mechanics by L.I. Schiff (Tata-McGraw-Hill)
2. Introduction to Quantum Mechanics by D.J. Griffiths (Pearson Education)
3. Quantum Mechanics by C. Cohen-Tannoudji, B. Diu and F. Laloe (Wiley VCH)
4. Quantum Chemistry by Ira N. Levine (Pearson Education)
5. Relativistic Quantum Mechanics by James D. Bjorken and Sidney D. Drell (McGraw-Hill)
6. An Introduction to Relativistic Quantum Field Theory by S.S. Schweber (Harper & Row)

Course Outcomes:

- The students will learn approximate methods for solving many body problems.
- Understand molecular electronic configurations and structure.
- Prepare for research in molecular, atomic and particle physics.

Major (Specialization):

Course Objective: Do deeper study in a specific branch of Physics, to inculcate self-study and get familiar with requirements of research. Students need to choose any one of the six major elective papers and corresponding practical course. These six courses are as follows:

PHY 517: Astrophysics- I: Credit 4+0

Unit – I

Elements of Optical and Radio Astronomy, **Celestial Sphere:** Spherical triangle, Coordinate systems; Altazimuth, Equatorial, Ecliptic and Galactic, **Time:** Sidereal time, Ephemeris and Universal time

Unit – II

Properties of Stars: Distance, Luminosity, Temperature, Colour of stars and their determination, Spectral types, H-R diagram, Boltzmann excitation equation, Saha's theory of thermal ionisation and its application, The MKK spectral classification

Unit – III

The Sun: Surface features; Evershed effect, Rotation, Magnetic field, Prominences, Photosphere, Chromosphere, Corona, Solar activity, Radio emission from the sun,

Planets: Periods, Orbits and phases of planets, Physical properties of planets and their satellites, Planetary rings, Asteroids, Comets and Meteors, Origin of the solar system

Unit – IV

Stellar Variability: Binary stars; visual, eclipsing and spectroscopic binaries, Determination of elements of a true orbit. Stellar masses and radii, Mass-luminosity relation, Stellar pulsation, Classical cepheids and RR Lyrae stars, Period-luminosity relation, Novae and supernovae.

References:

1. An Introduction to the Study of Stellar Structure by S. Chandrasekhar (Dover Publications)
2. Text book on Spherical Astronomy by W. M. Smart (Cambridge University Press)
3. Principles of Astronomy by S. P. Wyatt (Allen and Bacon, Inc.)
4. An Introduction to Astrophysics by B. N. Basu, T. Chattopadhyay, S. N. Biswas (Prentice Hall of India)
5. Astrophysics and Stellar Astronomy by T. L. Swihart (John Wiley and Sons, New York)
6. Stars, Galaxies by K. D. Abhyankar (University press)
7. Essentials of Astronomy by Lloyd Motz (Columbia University Press)
8. The Physical Universe by F. Shu (University Science Books, California, U.S.A.)

PHY-518: Biophysics-I: Credit 4+0

Unit – I

Nucleic Acids: Nucleosides and nucleotides, primary, secondary and tertiary structure of DNA, Watson - Crick model, backbone conformation, sugar puckering, different forms of DNA, Z-DNA, structure of RNA, different forms of RNA and their biological functions. The central dogma, DNA replication, RNA transcription and protein biosynthesis, reverse transcription, mutation and regulation of genes.

Unit – II

Proteins: Amino acids, peptide bond, disulphide bridge, Primary, secondary, (α - helix and β - sheet), tertiary and quaternary structure of proteins. Protein conformation, torsion and dihedral angles, Ramachandran map, structure of hemoglobin and myoglobin.

Unit – III

Membranes: Micelle. bilayer and liposome; structure of cell membrane, conformational properties of membranes, passive membrane transport; Donnan equilibrium, Hodgkin - Katz formula, Active membrane transport and transport of charged particles through membranes. Simple idea of molecular reception - smell reception and taste reception.

Unit – IV

Nerve Impulse: The Neuron, Axon and Action potential, recording of action potential, Chronaxie and rheobase; depolarization and repolarization of axon membrane, mechanism of propagation of nerve impulse; Ionic channels, Elementary idea of synaptic transmission.

References:

1. Molecular Biology of the Genes by J. D. Watson (Benjamin Inc, California)
2. Principles of Nucleic Acid Structure by W. Saenger (Springer Verlag, New York)
3. Biophysics; Ed. W. Hoppe et. al. , (Springer Verlag, New York)
4. Introduction to Biophysics by P.S. Narayanan
5. Biophysics by M. V. Volkenstein (MIR publishers)
6. Biophysics by V. Pattabhi & N. Gauttam
7. Intermolecular Interactions: From Diatomics to Biopolymers, Ed. B. Pullman (John Wiley, N. Y.)
8. Physical Biochemistry by K. E. van Holde, (Prentice Hall, N, J.)

PHY-519: Electronics - I: Credit 4+0

Unit – I

Analog and Combinational Logic Circuits: Analog computation, time and amplitude scaling, Analog to digital and digital to analog converter. Comparator, parity generator and checking, code conversion, Binary to gray and gray to binary. Logic design with MSI coder and decoder, multiplexer and demultiplexer circuits.

Unit – II

Sequential Circuits: Basic definition, finite state model SR, JK, T, D, Edge triggered flip flop, race condition and master slave flip flop, characteristic table and characteristic equation, sequential logic design state table, state diagram, state equation.

Unit – III

Registers and Counters: Register, shift register, universal shift register, Ring counter, twisted or Johnson counter, synchronous and asynchronous counters, UP/DOWN and scale of 2^n counter

Unit – IV

Microprocessor: Basic idea of magnetic memory, Ferrite core memory, semiconductor memory viz . RAM, ROM, PROM, EPROM, EEPROM. Introduction to intel 8085 microprocessor architecture, instruction and timings assembly language programming, stack and subroutine, code conversion.

References:

1. Digital Systems by J. Ronald Tocci
2. Digital Principles and applications by Malvino and Leach
3. Microprocessor by Goenkar

PHY-520: Solid State Physics I: Credit 4+0

Unit – I

Symmetry Properties of Crystal Lattice : Mathematical group representation, Double valued representation, The crystalline structure; Transformation of crystal lattice; Symmetries in Bravais lattice; Point groups; Space group; Classes, Transformation and construction.

Unit – II

Crystalline Solids: Free electron theory; Fermi gas at finite temperature, Mean energy, Methods of Energy Band Calculation; Electron dynamics in periodic lattice, Wigner-Seitz method and cohesive energy of metals, Orthogonalized plane wave(OPW), Pseudo potential, Augmented plane wave(APW) and Green function methods, Transition metal bands.

Unit - III

Fermi Surface: Construction of Fermi surface, Cyclotron resonance, Electron, hole and open orbits, Anomalous skin effect, De Haas Van Alphen effect.

Lattice Vibration and Thermal Properties: Quantization of lattice vibration, Phonon momentum Inelastic scattering of photon by photon and neutron by photon, Local phonon modes, phonon dispersion relation, Debye model of lattice heat capacity, Anharmonicity and thermal expansion.

Unit – IV

Disordered Materials: Structure, Short range order and dangling bond; Random network model; Amorphous semiconductor; Density of states and mobility gap; Electrical transport, Optical and switching properties.

References:

1. Principle of theory of solid by J.M. Ziman (Cambridge University Press, London)
2. Theoretical Solid State Physics Vol.1 and Vol.11 by W. Jones and N.H. March (John Wiley and Sons, London)
3. Quantum Theory of Solid by C. Kittel (John Wiley and Sons, London)
4. Quantum Theory of Solids by R.E. Peirls (Oxford University Press, London)

PHY-521: Spectroscopy and Lasers-I: Credit 4+0

Unit – I

Vector model for two and three valence electrons, Lande interval rule, Inverted terms and Hund's rule, Lande 'g' factor, spectral terms by magnetic quantum numbers.

Breadth of spectral lines, Intensity of spectral lines, Nuclear spin, Isotope effect and Hyperfine structure, Lamb shift.

Unit – II

Normal coordinate analysis: classical and quantum mechanical treatment of normal modes of vibration, vibrational selection rules, Fermi resonance, Vibrational and electronic spectra of benzene.

Unit – III

Rotational spectra of linear molecules like CO₂ and HCN, Rotational Raman spectra, Microwave spectra of ammonia.

Rotational structure of vibrational bands, Parallel and perpendicular bands of linear molecules like CO₂ and HCN and symmetric top molecules like NH₃, Coriolis interaction.

Unit – IV

Classification of electronic states, interaction of vibration and electronic motion, Renner-Teller effect, Coupling of rotation with vibration and electronic motion for linear molecules.

Allowed and forbidden electronic transitions, Isotope effect, Teller and Redlich product rule.

References:

1. Atomic spectra: H.E. White
2. Molecular spectra and Molecular structure Vol. I, II, III: G. Herzberg

PHY-522: X-Rays-I: Credit 4+0

Unit - I

Production of X-Rays, types of X-Ray tubes and auxiliary equipments. General features of continuous and characteristic spectra. Theories of the continuous spectrum : Stoke-Thompson pulse theory and Kramer's Wentzel theory of production of X-Rays by thin and thick targets.

Unit - II

Polarisation of X-Rays, Scattering of X-Rays by atoms and simple molecules. Atomic scattering factors and test of various theories. Scattering by gases and liquids. Compton scattering-Wave mechanical treatment. Klein-Nishina formula (no-derivation). Dispersion theory and reflection of X-Rays. Experimental methods of measuring refractive index. Anomalous scattering. Photoelectrons and their spatial distribution. Fluorescence yield.

Unit - III

X-Ray energy level diagrams, spin and screening doublet laws, multiple radiation and transition probabilities. Absorption spectra, Critical absorption edges. Theory of fine structure of absorption edges and absorption discontinuity.

Unit - IV

Soft X-Ray emission and absorption spectroscopy and its applications to band structure of solids. Effects of chemical combination on emission and absorption spectra. Forbidden lines. Relative intensities of X-Ray lines. Auger effect and satellite lines. X-Ray spectrographs-plane and bent crystal.

Course Outcomes:

- The students will learn specialized concepts of a specific branch of Physics.
- Will learn to independently reference multiple sources for advanced knowledge.
- Be prepared for research in chosen area of interest.

Physics Practical: Credit 0+4

Course Objectives:

Students will be required to perform at least five experiments from each course. They will have to maintain record books of experiments done for each course separately.

PHY-523: PHYSICS PRACTICAL-ASTROPHYSICS-I

1. Solar spectrum studies using 2 - m concave grating
2. Solar constant / Solar energy studies
3. Prism spectrograph
4. Orbital elements of Binary / Variable star study
5. Radial velocity determination including correction due to Earth's motion
6. Stellar spectral classification
7. Astronomical Project.

Or

PHY-524: PHYSICS PRACTICAL- BIOPHYSICS-I

1. Molecular modelling using crystallographic data
2. Electronic properties of biomolecules (CNDO method)
3. Ramchandran plot ($\phi - \psi$) of the peptides (PCILO method)
4. Molecular associations among nucleic acid bases
5. Absorption bands of chlorophyll using spectrophotometer
6. Emission spectra of Cu using Fe as standard
7. Rotational spectra of CN molecule
8. Dissociation energy of iodine molecule
9. Vibrational spectra of benzene

Or

PHY-525: PHYSICS PRACTICAL- ELECTRONICS-I

Analog Electronics:

1. Linear characteristics of Operational amplifier
2. Non-linear characteristics of Operational amplifier
3. Active filters using Operational amplifier
4. IC 555 Timer in different modes
5. Phase Locked Loops using IC 565 PLL
6. Sample and Hold circuit
7. Pulse amplitude modulation and demodulation
8. PAM, PPM, PWM modulation and demodulation

Or

PHY-526: PHYSICS PRACTICAL- SOLID STATE PHYSICS-I

1. X-ray powder diffraction
2. Laue photograph or rotation photograph
3. Experiment on lattice dynamics
4. Energy band gap by four probe technique
5. Dielectric constant of BaTiO₃ and Curie temperature
6. Ionic conductivity.

Or

PHY-527: PHYSICS PRACTICAL- SPECTROSCOPY and LASERS-I

Spectroscopy:

1. Verification of Cauchy's and Hartmann dispersion formula
2. Determination of the wavelength of Zn triplets
3. Dissociation energy of Iodine by absorption spectra in visible region
4. Rotational and Vibrational analysis of 3883 Å band system of CN molecule
5. Analysis of 2600 Å vibronic system of benzene
6. Study of the great Ca triads

Or

PHY-528: PHYSICS PRACTICAL- X-RAYS-I

1. Determination of wave length of X-ray source using plane crystal spectrograph for Copper target
2. Determination of wave length of X-ray source using plane crystal spectrograph for Molybdenum target
3. X-ray powder photograph of a metal
4. X-ray powder photograph of NaCl (non-metal)
5. Rotation photograph of an organic crystal
6. X-ray fiber photograph

Course Outcomes:

1. Developing research skills through its focus on writing and critiquing research proposals
2. Students will be prepared for higher research studies in various fields.

PHY-529: Masters Dissertation Project-I

Credit 4*

Course Objectives:

Students shall develop research skills through focused study of a research topic of choice. The students shall develop a research project under the mentorship of any faculty of the Department of Physics or any equivalent faculty or scientist as approved by the Department. The candidate will continue the research project in the X semester and shall make a presentation. The final Master's dissertation thesis shall be submitted in the final semester.

Course Outcomes:

- Student will learn presentation skills including making power point presentations etc.
- Students will get exposure to writing and reviewing research projects and will get motivated towards research as a career.

Semester-IV

PHY-530: Nuclear and Particle Physics: Credit 4+0

Course Objective: Understand nuclear structure, energy and concept of elementary particles.

Unit – I

Nuclear Models: Evidence of Nuclear shell Structure; Nuclear Potential and sequence of energy levels of nucleons, spin orbit potential and explanation of magic numbers, Collective model.

Nuclear Reactions: Cross section; partial wave analysis, optical theorem and shadow scattering, Compound nucleus hypothesis, Breit-Wigner one level formula, Direct Reactions; pickup and stripping reactions.

Unit – II

Nuclear Reactors: *Fission Reactor:* Neutron multiplication factor, Fermi's four factor formula,

resonance escape probability and thermal utilization factor, Basic reactor theory and reactor materials, Basic idea of breeding and fast neutron reactors.

Fusion Reactor: Fusion reaction, reaction rate and critical temperature, Lawson's criteria; magnetic confinement techniques, Tokamak and magnetic mirror devices.

Unit – III

Beta Decay: Pauli's neutrino hypothesis, Fermi theory of (β)-decay, Fermi-Kurie Plot and comparative half lives, selection rules and classification of transitions, Parity non-conservation and Wu's experiment.

Nuclear forces: Deuteron problem, low energy (n-p) and (p-p) scattering, scattering length, effective range theory, Spin-dependence of (n-p) interaction

Unit - IV

Elementary Particles: Fundamental interactions, Classification of elementary particles, symmetry and conservation laws, Elementary idea of CP and CPT invariance, Classification of Hadrons, Quantum numbers in strong interaction, Gell-Mann Nishijima formula, Lie algebra, SU(2)-SU(3) multiplets, Quark model of Hadrons.

References:

1. Nuclear Physics by Irvin Kaplan (Addison-Wesley)
2. Concepts of Nuclear Physics by B.L. Choen (Tata McGraw Hill)
3. Atomic and Nuclear Physics Vol II by S.N.Ghoshal (S. Chand and Co. Ltd.)
4. Nuclear Physics (Theory and Experiment) by R.R. Roy and B.P. Nigam (Wiley Eastern)
5. Nuclear Physics Vol I by Y M Shirikov and N P Yudin, (Mir Publisher, Moscow 1982).
6. Nuclear and Particle Physics by E.B. Paul (North Holland Publishing)
7. Facts and Mysteries in Elementary Particle Physics by M. Veltman (World Scientific)

Course Outcomes:

- The students will learn nuclear structure its energy and conservation laws.
- Understand elementary particles and symmetry considerations.
- Be prepared for research in areas related to nuclear and particle physics.

PHY-531: Lasers and Modern Optics: Credit 4+0

Course Objective: Understand advanced concepts of optics and their applications.

Unit - I

Laser: Einstein coefficients, Light amplification; Population inversion; pumping processes; rate equation for three and four level systems; Cavity modes, polarization of cavity media; Quality factor of cavity and ultimate line width, Characteristic properties, Basic principles of Ruby, He-Ne, CO₂.

Unit - II

Holography: Basic principle of holography, Method of hologram Recording and Reconstruction; Basic theory of plane hologram; practical consideration of holography and its application.

Unit - III

Non- Linear: Non-linear polarizability tensors, Coupled amplitude equation; Manely-Rowe relationship; Parametric amplification and oscillation, Phase matching, Second harmonic generation.

Fibre Optics: Types of fibres, Single mode and multi-mode fibres; dispersion and loss in fibre; Principles of optical communication, Optical elements.

Unit – IV

Quantum Optics: Spatial and temporal coherence, classical and quantum coherence function; Glauber's theory of optical coherence, Over completeness of coherent states and its properties; Quasi phase distribution function.

References:

1. Optical Coherence and Quantum Optics, L.Mandel and E.Wolf (Cambridge University Press, Cambridge, 1995)
2. Quantum Optics by M.O. Scully and M. Suhail Zubairy (Cambridge University Press, Cambridge, 1997)
3. Physics of Non-Linear Optics by Guang S. He and Song H. Liu(World Scientific Press, Singapore, 2003)
4. Laser and holographic Data processing by N. G. Bosov (Mir Publisher, Moscow)

Course Outcomes:

- The students will understand LASERs, wave guides and their applications.
- Understand non-linear optical phenomenon.
- Get familiar with coherence and basic concepts of quantum optics.

PHY-532: Condensed Matter Physics: Credit 4+0

Course Objective: Learn various important properties of materials and their applications.

Unit – I

Magnetic Properties: Magnetic ions, ground and excited states and multiplet separation; Paramagnetism of non-interacting magnetism ions and its application to transition and rare-earth ions.

Ferromagnetism: Molecular field theory, Heisenberg explanation of internal magnetic field, Landau theory of domain, Spin-wave theory, Magnon excitation and Bloch $T^{3/2}$ law, Antiferromagnetism, ferrimagnetism: Neel's two sub-lattice model.

Unit – II

Ferroelectricity: Basic features of piezo-, Pyro- and ferro electric materials; Order-disorder and displacive type ferro electric materials; Occurrence of ferroelectricity due to polarisation catastrophe and lattice modes; Devonshire theory of ferroelectric phase transition.

Unit – III

Superconductivity: Basic features (Zero resistance, Meissner effect, Penetration depth, Critical field, Heat capacity and isotopic shift) of superconductors, Soft and hard superconductors; Thermodynamics of superconducting transitions, London equation, Coherent length; Elements of BCS theory, Applications of superconductors: Particle tunneling and Josephson effect.

Unit - IV

Liquid crystals: Definition, Classification, Characteristic features; Thermotropic and Lyotropic Liquid Crystals, FLCs, Basic principle of LCDs.

Polymers: Structure, properties and methods of Polymerization, Degradation of Polymers, Viscoelastic state, Glass transition temperature.

Nano-materials: Definition, Types and characteristic features; Quantum size effect; density of states, Synthesis and characterization; Nanocomposites, Application in devices.

References:

1. Principle of theory of solid by J.M. Ziman (Cambridge University Press, London)
2. Theoretical Solid State Physics Vol.1 and Vol.11 by W. Jones and N.H. March (John Wiley and Sons, London)
3. Quantum Theory of Solid by C. Kittel (John Wiley and Sons, London)
4. Quantum Theory of Solids by R.E. Peirls (Oxfbrd University Press, London)
5. Nanotechnology: Principles and Practices, S.K. Kulkarni, Capital Pub. Co., New Delhi, 2006
6. Liquid Crystals by S. Chandrashekhar, (Cambridge Univ. Press, London)
7. An Introduction to Polymer Physics by I. I. Perepechko (Mir Publishers)

Course Outcomes:

- The students will learn about different and important types of materials.
- Understand various useful applications of materials.
- Students will be prepared for research in any area of condensed matter physics.

Major (Specialization):

Course Objective: Do deeper study in a specific branch of Physics, to inculcate self-study and get familiar with requirements of research. Students needs to continue with the same major elective paper and corresponding practical course as opted by them in Semester IX. The six courses are as follows:

PHY 533: Astrophysics II: Credit 4+0

Unit – I

Basic Astrophysics: Hydrostatic equilibrium, Lane - Emden equation, Equation of radiative transfer, Local thermodynamical relation, Radiative equilibrium, Mass-luminosity relation, Stability conditions for convective and radiative equilibrium. Curve of growth.

Unit – II

Stellar Energy: Gravitational contraction, pp cycle, CN cycle and triple alpha – process. Evolutionary sequence of stars, White dwarfs; Structure of envelope and interior, Elementary ideas of neutron stars, Pulsars and Black holes

Unit – III

The Milky Way; Distribution of stars, Interstellar gas and dust, Luminosity function, Star counts, Spiral structure. Galactic rotation, Oort's constant, Mass distribution, 21-cm radiation and Galactic structure

Unit – IV

External Galaxies; Classification, Mass and other physical properties, Radio Galaxies, Active Galaxies, Quasars, Cosmology; Olber's paradox, Newtonian cosmology, Expanding universe, Cosmological postulates, Cosmological red-shift, Big-bang model, Steady state theory.

References:

1. Principles of Astronomy by S. P. Wyatt (Allen and Bacyon, Inc.)
2. An Introduction to Astrophysics by B. N. Basu , T. Chattopadhyay, S. N. Biswas (Prentice Hall of India)
3. Astrophysics and Stellar Astronomy by T. L. Swihart
4. Astrophysics: Stars and Galaxies by K. D. Abhyankar
5. Essentials of Astronomy by Lloyd Motz (Columbia University Press)
6. The Physical Universe by F. Shu (University Science Books, California, U.S.A.)
7. The Structure of Universe by J. V. Narlikar (Oxford University Press)

PHY-534: Biophysics -II: Credit 4+0

Unit - I

Radiation Biophysics: Types of ionizing radiations, interaction between radiation and matter, radiation dose and dose rate, radiation effect on living cell, protein, nucleic acid and membrane. Radiation hazards and radiation protection.

Photobiophysics: Chemical structure and properties of chlorophyll, mechanism of photosynthesis, photochemical systems: PS-I and PS-II, Importance of photosynthesis.

Unit - II

Intermolecular Interactions : Intermolecular potential functions, Rayleigh - Schrodinger perturbation theory of long - range intermolecular interactions, classification of intermolecular forces, concept of short - range forces and inadequacy of Rayleigh - Schrodinger treatment at short range. Representation of short - range forces by classical and semi - empirical methods. Equivalence of classical and quantum - mechanical forces. Multicentred - multipole representation of intermolecular interactions.

Unit - III

X - ray methods: Basic principle of X - ray diffraction, structure factor, Analysis of Laue, Rotation and Powder photographs.

NMR: Basic theory of Nuclear Magnetic Resonance, Chemical shift and spin-spin coupling, relaxation effect, NMR spectrometers and FT spectroscopy, Applications.

Unit - IV

ORD and CD: Basic concept of circular dichroism and optical rotation, Drude equation, Molecular basis of rotatory power, Rotatory behaviour of macromolecules, Moffit plots for helical and random coil structure.

Sedimentation: Sedimentation velocity, apparatus and procedures for sedimentation studies, sedimentation equilibrium, Archibald method; Density gradient sedimentation.

Electrophoresis: Transport in an electric field, isoelectric focussing, orientation of molecules in electric fields.

Chromatography: Basic idea of Molecular - Sieve chromatography; Gel filtration, analysis of the shape of eluting bands; Determination of shape and size of macromolecules.

References:

1. Molecular Biology of the Genes by J. D. Watson (Benjamin Inc, California)
2. Principles of Nucleic Acid Structure by W. Saenger (Springer Verlag, New York)
3. Biophysics; Ed. W. Hoppe et. al. , (Springer Verlag, New York)
4. Introduction to Biophysics by P.S. Narayanan
5. Biophysics by M. V. Volkenstein (MIR publishers)
6. Biophysics by V. Pattabhi & N. Gauttam
7. Intermolecular Interactions: From Diatomics to Biopolymers, Ed. B. Pullman (John Wiley, N. Y.)
8. Physical Biochemistry by K. E. van Holde, (Prentice Hall, N, J.)

PHY-535: Electronics – II: Credit 4+0

Unit - I

Communication Theory: Types of Noise and its Spectrum, S/N ratio in analog communication systems, information content of message, rate of information-transmission in discrete communication channels, channel capacity, Shannon- Hartly Theorem and its applications.

Unit - II

Analog Modulation: Sampling of analog signals, sampling theorem, Types of modulation and generation: PAM, PPM, and PWM; Quantization of Analog signals: Uniform and Non-uniform.

Unit - III

Digital Modulation: Pulse code modulation, Binary coding and PCM bandwidth DPCM, DM and ADM, ASK and FSK system, transmission and detection of binary system.

Unit - IV

Microwaves and Antenna: Microwave generation, Reflex Klystron Oscillator, Transfer Electron Effect :Gun Diode, Tunnel diode, IMPATT. Current and voltage distribution in antenna, Short electric dipole, linear and ground antenna, field -distribution around vertical antenna, antenna arrays.

References:

1. Communication Systems by B. P. Lathi (Oxford University Press)
2. Principles of Communication System by Taub & Schilling (Mc Graw Hill)
3. Microwave by K. C. Gupta (Wiley Eastern Limited)
4. Antennas and Wave Propagation by J.D. Kraus (Tata Mc Graw Hill Publishing Company Limited -2010)

PHY-536: Solid State Physics II: Credit 4+0

Unit – I

Transport Properties: Linearized Boltzmann transport equation, Electrical conductivity, Relaxation time, Impurity scattering, Ideal resistance, Carrier mobility, General transport coefficient; Thermal conductivity, Thermoelectric effects, Lattice conduction, Phonon drag, Hall effect and magnetoresistance.

Unit – II

Superconductivity: Electron-electron interaction and screening, electron-phonon-electron interaction and Cooper pairs, Salient features of BCS theory, Superconducting ground state, Quasi particle and energy gap, High T_c superconductors; Charge transfer model of Cuprates, Defect ordering.

Unit – III

Magnetic Resonance: General theory of magnetic resonance and Bloch equations, Electron paramagnetic resonance (EPR): Method of observation, Structure of resonance lines and their uses; Nuclear magnetic resonance (NMR): Salient theory and method of observation, Structure of resonance lines and their uses.

Unit – IV

Mossbauer Effect: Difficulties in observing resonance fluorescence of nuclear system, Recoil energy, Natural and dipole broadenings, Classical and quantum theories of Mossbauer effect, experimental method and principal uses of Mossbauer effect.

References :

1. Principle of theory of solid by J.M. Ziman (Cambridge University Press, London)
2. Theoretical Solid State Physics Vol.1 and Vol.11 by W. Jones and N.H. March (John Wiley and Sons, London)
3. Quantum Theory of Solid by C. Kittel (John Wiley and Sons, London)
4. Quantum Theory of Solids by R.E. Peirls (Oxfbrd University Press, London)
5. Mossbauer Effect and its Application by V. G. Bhide
6. Principles of Magnetic Resonance by C.P. Slichter (Horper and Row, NewYork)

PHY-537: Spectroscopy and Lasers-II: Credit 4+0

Unit - I

Laser Physics: Rate equations for three and four level systems, Resonant modes of optical cavities, Mode size and cavity stability, Q factor and resonance line width, Q switching, Techniques of Q switching, Pockel's effect and mode locking.

Unit - II

Laser Systems: Pulsed crystal lasers, Rare earth ion lasers, Actinide ions and Transition metal ion lasers, Effects of crystal imperfections on laser behaviour, Ga-As injection laser, Tunable dye lasers and colour centre lasers.

Unit - III

Holography: Description of holography, Recording of plane and volume holograms, Holographic interferometry. Applications of holography.
Raman and Brillouin Scattering

Unit - IV

Non Linear Optics: Induced polarization, Parametric amplification, second and third harmonic generation, Parametric light oscillator and Frequency upconversion.

Laser Spectroscopy: Resonance Raman Spectroscopy, Laser investigations in atmospheric pollution monitoring and Picosecond spectroscopy.

References:

1. Atomic and Laser spectroscopy: Alan Corney
2. Lasers vol I and vol II: Edited by A.K.Levine
3. Principles of Holography: Howard M. Smith
4. Laser Applications: Monte Ross
5. Laser Spectroscopy: Edited by J.L.Hall
6. Lasers and Non-linear optics: B.B.Laud

PHY-538: X-Rays - II: Credit 4+0

Unit – I

Crystal systems, Bravais lattices. Symmetries in crystals. Point groups. Space lattices, Unit cells, Lave spots, space groups. Concept of reciprocal space and reciprocal lattice. Theory of diffraction of X-Ray by crystals. Lave equations and their interpration by Bragg. Interpretation of Bragg's law in terms of reciprocal lattice-Ewald's construction. Atomic scattering factors and structure factors. Systematic abstnecs and absolute intensity.

Unit - II

Theory of reflection of X-Rays from mosiac and perfect crystals. Effect of thermal agitation. Diffuse reflections. Various types of X-Ray photographs Lave, Debye-Scherrer, rotation. Oscillation, Weissenberg and precession and their interpretation.

Unit - III

Elementary idea of X-Ray diffractometers. Diffraction of X-Rays by fibres and amorphous solids. Effects of grain size in polycrystalline aggregates. Fourier methods for mapping electron densities in crystals. Phase problem in structure analysis. Patterson synthesis. Elementary idea of (i) direct methods for phase determination and (ii) difference Fourier and least-squares methods of refinement.

Unit – IV

Elementary idea of electron and neutron diffractions methods and their comparison with X-Ray diffraction methods. Alloys: order-disorder phenomenon and phase transformations, superlattice.

Course Outcomes:

- The students will learn specialized concepts of a specific branch of Physics.
- Will learn to independently reference multiple sources for advanced knowledge.
- Be prepared for research in chosen area of interest.

Physics Practical: Credit 0+4

Course Objectives:

Students will be required to perform at least five experiments from each course. They will have to maintain record books of experiments done for each course separately.

PHY-539: PHYSICS PRACTICAL-ASTROPHYSICS-II

1. Familiarity with the night sky using Celestial globe and star maps
2. Diurnal motion study using telescope
3. Angular separation between stars using telescope
4. Use of Theodolite (Transit measurement; Coordinates of the stars)
5. Rising and Setting time of Planets and stars using Almanac
6. Lunar Photography
7. Stellar Photometry

Or

PHY-540: PHYSICS PRACTICAL- BIOPHYSICS-II

1. X - ray powder photograph
2. Fibre photograph
3. Plane crystal photograph
4. Ultrasonic studies of binary liquids
5. Molecular weight of a polymer using Viscometer
6. Optical rotatory dispersion study of dextrose
7. Paper / Thin layer / Column chromatography
8. Study of electrophoresis bands
9. Recording and analysis of ECG

Or

PHY-541: PHYSICS PRACTICAL- ELECTRONICS-II

Digital Electronics:

1. Combinational circuits
2. Sequential circuits
3. Characteristics of TTL logic
4. Multiplexer and Demultiplexer circuits
5. Semiconductor memory using IC 7489 RAM
6. D / A and A / D converters
7. Encoder and Decoder
8. Microprocessor 8085 - I
9. Microprocessor 8085 – II

Or

PHY-542: PHYSICS PRACTICAL- SOLID STATE PHYSICS-II

1. Thermoelectric power
2. E. P. R.
3. Magnetic susceptibility
4. Electro-Luminescence
5. B.H. curve (Hysteresis loss) by C.R.O
6. Hall effect

Or

PHY-543: PHYSICS PRACTICAL- SPECTROSCOPY and LASERS-II

Lasers:

1. Determination of wavelength of laser by grating (transmission / reflection)
2. Power distribution within the laser beam
3. Spatial coherence with Young's double slits
4. Spot size and divergence of a laser beam
5. Raman spectrum of CCl_4
6. Study of speckle phenomenon

Or

PHY-544: PHYSICS PRACTICAL- X-RAYS-II

1. X-ray emission spectrum using bent-crystal spectrograph for Copper target
2. X-ray emission spectrum using bent-crystal spectrograph for Molybdenum target
3. X-ray absorption spectrum using bent-crystal spectrograph
4. Oscillation photograph of an organic crystal
5. Weissenberg photograph of a crystal
6. Study of absorption edge of Silver

Course Outcomes:

1. Developing research skills through its focus on writing and critiquing research proposals.
2. Students will be prepared for higher research studies in various fields.

PHY-545: Masters Dissertation Project-II

Credit 4*

Course Objectives:

Students shall develop research skills through focused study of a research topic of choice. The students shall develop a research project under the mentorship of any faculty of the Department of Physics or any equivalent faculty or scientist as approved by the Department. The candidate will continue the research project from the IX semester and shall make a presentation as well as submit a Master's dissertation thesis.

Course Outcomes:

- Student will learn presentation skills including making power point presentations etc.
- Students will get exposure to writing and reviewing research projects and will get motivated towards research as a career.

Minor Elective

PHY-546: Elementary Atmospheric Physics: Credit 4+0

Course Objectives: The course will provide basic concepts about earth atmosphere and the Physics involved therein.

Unit - I

Basic concept of different layers of our atmosphere and their coupling. Composition of troposphere, Lapse rate.

Unit – II

Hydrostatic equilibrium, application of basic concepts of Thermodynamics, Basic concept of radiation, Solar parameters and solar constant.

Unit – III

Composition of Stratosphere, Ozone hole over Antarctica and different theories, Atmospheric response due to different pollutants.

Unit – IV

Natural calamities, Global warming and Recent climate change, Basic concept of Lightning activity, Earthquake, Heat stroke, Thunderstorm, Cyclone and flood.

References:

1. Atmospheric Sciences: An Introductory Survey- J.M. Wallace and P.V. Hobbs, Elsevier Academic Press, 2006
2. An Introduction to Atmospheric Physics, D. G. Andrews, Cambridge University Press, 2010.

Course Outcomes:

- A broad overview of the earth atmosphere will be obtained.
- The students will understand the application of basic Physics in the Atmosphere.
- The climatic impact of different phenomenon will be understood.

Minor Elective

PHY-547: Frontiers of Physics: Credit 4+0

Course Objectives: The understanding of fundamentals of Physics and applications popular in the present scenario will be provided.

Unit – I

Classification of Elementary particles, Leptons, Baryons, conservation laws.

Unit – II

Nuclear Forces and the Quark model. Outline of the LHC experiment.

Unit – III

Definition of nano-dimensional materials - Historical milestones - Unique properties due to nano size, Classification of Nanomaterials, Nanofabrication methods- Bottom-up and top-down approaches.

Unit – IV

Carbon nanostructures, Soft Nanocomposites, Biomolecular Nanostructures, Biological and Chemical applications.

References:

1. Facts and mysteries in elementary particle physics, M. J. G. Veltman, World Scientific publishing, 2003.
2. Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, G. Cao, World Scientific, 2011.

Course Outcomes:

- The student will be introduced to the latest applications of Physics.
- Familiarity with basic concepts of elementary particles and nanotechnology.