M. Sc. PHYSICS

Course Structure & Scheme of the Programme



Department of Physics
National Institute of Technology (NIT),
Hamirpur – 177005
Himachal Pradesh, INDIA
http://www.nith.ac.in/Phys/

Introduction of the Programme

The Department of Physics proposes to start Post Graduate Programme in Physics (M. Sc. Physics). The main aim of the proposal is to develop and produce a skilled manpower well equipped with fundamentals of theoretical, experimental, computational knowledge in the field of Physics as there is a need for specialized work force in this fast growing area.

This Programme will boost the Engineering and Technical streams in addition to strengthening of science stream. There is a need to train and skill students in this rapidly growing field in which requirement of highly skilled manpower in Physics tools and their implementation is increasing day-by-day. The students have to be imparted knowledge pertaining to this field as per requirements of society, scientific and technological Industries. From the very start, this department has shared the vision of the Institute in striving for excellence in research and teaching activities.

The faculty is well qualified and competent to run the proposed Programme. The faculty of Physics is actively engaged in research activities and has vast experience of guiding Ph.D. scholars in addition to execution of R&D Projects from various funding agencies such as DRDO, DST, IUAC and MHRD etc. They have volume of research publications at National and International levels to their credit.

Experimental and computational facilities including internet are also available in the department and the Institute to carry out practical and R&D activities. The institute library houses sufficient books and journals & periodicals to run this course. Care has been taken to include wide range of topics of Physics and field related to scientific research in addition to its applications to engineering, physical sciences and allied fields. The duration of the course is two years which will spans over 4 semesters.

The course objective is to produce students with good fundamental, applied & computing background in Physics. Successful students will be able to pursue career in teaching, R&D Labs, industries or in computational related jobs.

Course Detail

Programme	**M. Sc. In Physics**
Year of starting	**July, 2017**
Duration (Total)	**2 years (4 Semesters)**
Admission	**Centralized Counselling through CCMN (Centralized Counselling for M.Sc./M.Sc.(Tech.) admissions to NITs and CFTIs)on the basis of rank of JAM (Joint Admission Test for M.Sc.) and Institute Entrance Test for remaining vacant seats**
Eligibility	• **B.Sc. (Pass or Hons.) examination from UGC recognised Universities with 60% marks (General/OBC), 55% marks in case of SC/ST and PwD Category** **or** • **Any other exam recognized as equivalent there to with Physics and Maths as main subjects**
Intake	**20**
Reservation	**As per MHRD norms**

Course Structure and Scheme of the Programme

Semester I

Code No.	Subject Name	L - P	Credits
PHY-511	Classical Mechanics	**3 - 0**	**3**
PHY-512	Quantum Mechanics - I	**3 - 0**	**3**
PHY-513	Mathematical Physics	**3 - 0**	**3**
PHY-514	Electrodynamics	**3 - 0**	**3**
PHY-515	Atomic and Molecular Spectroscopy	**3 - 0**	**3**
PHY-519	Laboratory - I	**0 - 6**	**4**
Total		**15- 6**	**19**

Semester II

Code No.	Subject Name	L - P	Credits
PHY-521	Quantum Mechanics - II	**3 - 0**	**3**
PHY-522	Numerical Methods and computational Techniques	**3 - 0**	**3**
PHY-523	Thermodynamics and Statistical Physics	**3 - 0**	**3**
PHY-524	Solid State Physics	**3 - 0**	**3**
	Elective - I	**3 - 0**	**3**
PHY-529	Laboratory - II	**0 - 6**	**4**
Total		**15 -6**	**19**

Semester III

Code No.	Subject Name	L - P	Credits
PHY-531	Electronics	**3 - 0**	**3**
PHY-532	High Energy Physics	**3 - 0**	**3**
	Elective - II	**3 - 0**	**3**
PHY-538	Laboratory - III	**0 - 6**	**4**
PHY-539	Dissertation , Part-I	**0 - 10**	**5**
Total		**9 -16**	**18**

Semester IV

Code No.	Subject Name	L - P	Credits
PHY-541	Nuclear Physics	**3-0**	**3**
	Elective - III	**3-0**	**3**
PHY-549	Dissertation , Part-II	**0-18**	**8**
Total		**6-18**	**14**

Total number of credits covered in four semesters = 19+19+18+14 = 70

List of Elective -I

Code No.	Subject Name	L - P	Credits
PHY-525	Experimental Techniques in Physics	**3-0**	**3**
PHY-526	Polymer & Liquid Crystals	**3-0**	**3**
PHY-527	Nanostructured Materials	**3-0**	**3**

List of Elective -II

Code No.	Subject Name	L - P	Credits
PHY-533	Opto Electronics	**3-0**	**3**
PHY-534	Microwaves Electronics	**3-0**	**3**
PHY-535	Plasma Physics	**3-0**	**3**

List of Elective –III

Code No.	Subject Name	L - P	Credits
PHY-542	Nuclear Accelerator and Radiation Physics	**3-0**	**3**
PHY-543	Nuclear Instrumentation	**3-0**	**3**
PHY-544	Quantum Field Theory	**3-0**	**3**

Scheme of Examination

The evaluation is continuous and spread across entire semester with distribution of marks/weightage as under:

A. Theory Courses

S. No.	Particulars	Weightage
1.	Mid Semester Examination	20% (duration 1½ Hours)
2.	Class test(s) (to be conducted by the concerned teacher)	10%
3.	Assignments, quizzes, projects, attendance etc.	10%
4.	End Semester Examination	60% (duration 03 Hours)

No student can pass a theory course without securing at least one third of the maximum marks in end semester examination.

B. Laboratory Courses

S. No.	Particulars	Weightage
1.	Record Mark (based on continuous assessment of Lab/ Practical works considering regularity and timely submission of Lab records)	30%
2.	Viva-Voce-I	20%
3.	Lab Experiment/ Procedure Writing/ Tabulation/ Innovation, etc. as applicable	30%
4.	Viva-Voce-II	20%

C. Dissertation

S. No.	Particulars	Weightage	Remarks
1.	Seminar-I	30%	To be awarded by the evaluation committee on the basis of Presentation deliver by the students and Response to Questions/Queries Raised at the end of 3rd semester.
2.	Seminar-II	30%	To be awarded by the evaluation committee on the basis of Presentation deliver by the students and Response to Questions/Queries Raised at the end of 4th semester.
3.	Final Evaluation	40%	To be evaluated and awarded by the Supervisor

NOTE:

1. The total number of credits of the Programme = 70
2. Each student shall be required to appear for the examination in all courses.
3. Dissertation topic will be allotted to students in the beginning of third semester.

NATIONAL INSTITUTE OF TECHNOLOGY
DEPARTMENTOF PHYSICS

Courses of Study and Syllabi for M. Sc. Physics
(Effective from the Session July 2017 onwards)

		Max. Marks
Semester I		
PHY-511	Classical Mechanics	100
PHY-512	Quantum Mechanics - I	100
PHY-513	Mathematical Physics	100
PHY-514	Electrodynamics	100
PHY-515	Atomic and Molecular Spectroscopy	100
PHY-519	Laboratory – I	100
Semester II		
PHY-521	Quantum Mechanics - II	100
PHY-522	Numerical Methods and computational Techniques	100
PHY-523	Thermodynamics and Statistical Physics	100
PHY-524	Solid State Physics	100
	Elective –I	100
PHY-529	Laboratory-II	100
Semester III		
PHY-531	Electronics	100
PHY-532	High Energy Physics	100
	Elective –II	100
PHY-538	Laboratory-III	100
PHY-539	Dissertation Part -I	100
Semester IV		
PHY-541	Nuclear Physics	100
	Elective –III	100
PHY-549	Dissertation Part -II	200

SEMESTER I

PHY -511 CLASSICAL MECHANICS

Lagrangian Mechanics: Newton's laws of motion, mechanics of a system of particles, constrain, D'Alembert's principle and Lagrange equations of motion. Velocity dependent potentials and dissipation function. Some applications of Lagrangian formulation, Hamilton's principle, derivation of Lagrange equations from the Hamilton's principle. Conservation theorems and symmetry properties.

Central Force Problem : Two body central force problem, reduction to equivalent one body problem, the equation of motion and first integrals, the equivalent one dimensional problem and classification of orbits. The differential equation for the orbit and integrable power-law potential. The Kepler problem. Scattering in a central force.

Rigid Body Dynamics: The independent coordinates of a rigid body, orthogonal transformations, the Euler's angles. Euler's theorem on the motion of rigid body, finite and infinitesimal rotations, rate of angular momentum and kinetic energy about a point for a rigid body, the inertia tensor and moment of inertia, the eigenvalues of moment of the inertia tensor and the principal axes transformation. Euler's equations of motion, torque free motion of a rigid body.

Canonical Transformations and Hamilton-Jacobi Theory: Legendre transformation and Hamilton's equations of motion, cyclic coordinates and conservation theorems, derivation of Hamilton's equations from a variational principle, the principle of least action. The equation of canonical transformations, examples of canonical transformations, Poisson brackets. Equations of motion, infinitesimal canonical transformation and conservation theorems in the Poisson bracket formulation. The Hamilton-Jacobi equation for Hamilton's Principal Function, The harmonic Oscillator Problem as an example of the Hamilton-Jacobi method.

Books Recommended:

1. Goldstein H "Classical Mechanics", Narosa Publishing House, New Delhi, (2004).
2. Landau L D and Lifshitz E M "Mechanics", Pergamon Press, Oxford, (1989).
3. Aruldhas G "Classical Mechanics", PHI Learning Pvt. Ltd., Delhi, (2013).
4. Rana N C and Joag P S "Classical Mechanics", Tata McGraw-Hill Publishing Co., New Delhi.
5. Shankara Rao "Classical Mechanics", Prentice Hall of India, New Delhi, (2005.

PHY -512 QUANTUM MECHANICS – I

Linear Vector Space and Matrix Mechanics: Vector spaces, Schwarz inequality, Orthonormal basis, Schmidt orthonormalisation method, Operators, Projection operator, Hermitian and Unitary operators, change of basis, Eigenvalue and Eigenvectors, Dirac's bra and ket notation, commutators, Simultaneous eigenvectors, Postulates of quantum mechanics, uncertainty relation. Harmonic oscillator in matrix mechanics, Time

development of states and operators, Heisenberg and Schrodinger representations, symmetries and conservation laws, parity operator, Exchange operator and identical particles.

Stationary State Approximate Methods: Variational method with application to the ground states of harmonic oscillator, Hydrogen atom, Helium atom; WKB method: Bound states for potential with and without rigid walls, tunnelling through the barrier

Angular Momentum: Solution of the Schrodinger equation for a spherically symmetric potential, orbital angular momentum operator. Eigenvalues and eigenvectors of L2 and Lz. Spin angular momentum, General angular momentum, Eigenvalues and eigenvectors of J2 and Jz. Representation of general angular momentum operator, Addition of angular momenta, C.G. coefficients.

Books Recommended:

1. Sakurai J.J. "Modern Quantum Mechanics", Pearson Education Pvt. Ltd., New Delhi, 2002.
2. Mathews P.M. and Venkatesan K. "A Text Book of Quantum Mechanics", Tata McGraw- Hill Publishing Company, New Delhi, 1981.
3. Khanna M.P. "Quantum Mechanics", Har Anand, New Delhi, 1996.
4. Thankappan V.K. "Quantum Mechanics", Wiley Eastern, New Delhi, 1985.
5. Powell J.L. and Crasemann B "Quantum Mechanics", Narosa Publishing House, New Delhi.
6. Merzbaber E. "Quantum Mechanics", John Wiley & Sons, Inc., New York, 1970

PHY -513 MATHEMATICAL PHYSICS

Vector Calculus & Tensors: Curvilinear coordinates, differential vector operators in curvilinear coordinates, spherical and cylindrical systems, general coordinate transformation, tensors; covariant, contravariant and mixed, algebraic operations on tensors.

Complex Analysis: The Cauchy-Riemann conditions, Cauchy integral theorem, Cauchy integral formula, Taylor and Laurent series, singularities and residues, Cauchy residue theorem, Calculation of real integrals.

Laplace transforms: Definitions, Conditions of existence, functions of exponential orders, Laplace transform of elementary functions, Basic theorems of Laplace transforms, Laplace transform of special functions, Inverse Laplace transforms, its properties and related theorems, convolution theorem, use of Laplace transforms in the solution of deferential equation with constant and variable coefficients and simultaneous differential equations.

Fourier Transformation: Fourier decomposition, Fourier series, and convolution theorem. Fourier transformations and its application to wave theory.

Differential Equations: Second order differential equation, Frobenius method, Wronskian and a second solution, The Sturm Lioville problem, One dimensional Green's functions, Partial differential equation, Laplace equation, Possion equation, Boundary value problem.

Special Functions: Gamma function, the exponential integral and related functions, Bessel functions of the first and second kind, Legendre polynomials, associated legendre polynomials and spherical harmonics, Generating functions for Bessel, legendre and associated legendre functions.

Group Theory: Definition of a group, Multiplication table, Conjugate elements and classes of groups, directs product, Isomorphism, homeomorphism, permutation group, Definitions of the three dimensional rotation group and SU(2).

Books Recommended:

1. George Arfken " Mathematical Methods for Physists", Academic Press, San Diego, U.S.A
2. Harvil and Pipes L.A "Mathematical Methods for Physicists and Engineers" Tata McGraw-Hill Publishing Company, New Delhi, 1958.
3. Rajput B.S. "Mathematical Physics" Pragati Prakashan, Meerut, 2005.
4. Speigal M.R. "Laplace Transforms", Schaum Series Tata McGraw-Hill Publishing Company, New Delhi, 1981.
5. Kreyszig E. "Advanced Engineering Mathematics", 8th Ed., John Wiley & Sons, New York, 2001.
6. Joshi A.W. "Matrices and Tensors in Physics", 3rd Ed., New Age International Publishers, New Delhi, 1995.

PHY-514 Electrodynamics

Electrostatics: Introduction, Work and Energy in electrostatics, Polarization, Laws of electrostatic field in the presence of dielectrics, Energy of the field in the presence of a dielectric, Boundary condition, Poisson and Laplace equations, Earnshaw's theorem, Boundary conditions and Uniqueness theorem, Multipole expansion, Method of electrostatic images.

Magnetostatics: Introduction, Laws of magnetostatics, Magnetic scalar and vector potentials, Magnetic media, magnetization, magnetic field vector, Boundary conditions.

Time Varying Fields: Maxwell's equations, Displacement current, Electromagnetic potential, vector and scalar potential, Gauge transformations; Lorentz and Coulomb Gauge, Poynting theorem, conservation laws for a system of charged particles and electromagnetic field, continuity equation.

Electromagnetic Waves: Plane waves in Non-conducting and conducting media Polarization- linear and circular polarization. Skin effect, Reflection and refraction of electromagnetic waves across a dielectrics interface at a plane surface between dielectrics. Total internal reflection, Polarization by reflection, Reflection from the surface of a metal.

Electromagnetic Radiation: Retarded Potentials, Radiation from an oscillating Dipole, Lienard-Wiechert Potentials, Potentials for a charge in uniform motion-Lorentz Formula, Fields of an accelerated charge.

Books Recommended:

1. Jackson J.D. "Classical Electrodynamics", John Wiley & Sons Pvt. Ltd., New York, 2004.
2. Griffiths D.J." Introduction to Electrodynamics", Pearson Education Pvt. Ltd., New Delhi, 2002.
3. Marian J.B and Heald M.A. "Classical Electromagnetic Radiation", Academic Press, New Delhi,
4. Puri S.P. "Classical Electrodynamics", Tata McGraw-Hill Publishing Company, New Delhi.
5. Jordon E.C. and Balmain K.G. "Electromagnetic Waves and Radiating Systems", Prentice Hall of India, New Delhi, 1995.

PHY-515 Atomic and Molecular Spectroscopy

Quantum States of One Electron Atom: Atomic orbitals-Hydrogen spectrum – The Pauli Exclusion Principal – Ritz combination principal Spectra of alkali elements, Spin – orbit interaction; Larmor's theorem and the fine structure in alkali spectra – Equivalent and non-equivalent electrons-penetrating and non-penetrating orbits, quantum defect and screening parameter, selection rules and intensity rules, breadth of spectrum-Doppler effect, Natural breadth, external effects.

Two Electron Systems: General characteristics of the energy levels of alkaline earth elements; selection rules and intensity rules, Interaction energy in LS or Russell-Saunder's coupling and JJ coupling – in LS coupling, Hyper fine structure (qualitative) Normal and Anomalous Zeeman effect-Paschen Backeffect, Stark effect, Lande's g factor in LS coupling.

Molecular Structure: Types of molecules-Diatomic linear symmetric top, asymmetric top and spherical top molecules-Rotational Spectra of diatomic molecules as a rigid rotator-Energy levels and spectra of non rigid rotor-intensity of rotational lines Vibrational energy of diatomic molecule as a simple harmonic oscillator – Energy levels and spectrum – Morse potential energy curve-Molecules as vibrating rotator – Vibration spectrum of diatomic molecule – PQR branches IR spectrometer (qualitative).

Spectroscopy: Raman effect – Quantum theory- Molecular polarisability – Pure rotational spectra of diatomic molecules – Vibration rotation Raman spectrum of

diatomic molecules – intensity alteractions in Raman spectra of diatomic molecules-Experimental set up for Raman spectroscopy – Application of IR and Raman spectroscopy in the structure determination of simple molecules Born Oppenheimer approximation – Franck Condon principle – dissociation and pre-dissociation – Dissociation energy.

Books Recommended:

1. Introduction to Atomic Spectra: H.E. White Tata Mcgraw Hill.
2. Fundamentals of molecular spectroscopy: C.B. banwell
3. Spectroscopy Vol. I, II & III: Walker & Straughen
4. Introduction to Molecular spectroscopy: G.M. Barrow
5. Spectra of diatomic molecules: Herzberg
6. Molecular spectroscopy: Jeanne L McHale
7. Molecular spectroscopy: J.M. Brown
8. Spectra of atoms and molecules: P.F. Bermath
9. Modern spectroscopy: J.M. Holias
10. Electromagnetic: B.B. Laud

PHY-519 LABORATORY - I

The Lab will be twice in a week, each of three hours duration. Students will perform at least twelve experiments in this lab session.

SEMESTER II

PHY -521 QUANTUM MECHANICS – II

Scattering Theory: Scattering Cross-Section and scattering amplitude, partial wave analysis, Low energy scattering, Green's functions in scattering theory, Born approximation and its application to Yukawa potential and other simple potential. Electron scattering by an atom. Optical theorem, Scattering of identical particles.

Perturbation Theory: An introduction to perturbation theory; its relevance, and physical examples, Time-independent perturbation theory: non-degenerate case, Time-independent perturbation theory: degenerate case, Time- dependent perturbation theory; atom- field interactions and the dipole approximation, Fermi's golden rule and its application to radiative transition in atoms, Selection rules for emission and absorption of light.

Relativistic Quantum Mechanics: Klein-Gordon equation, Dirac equation and its plane wave solutions, significance of negative energy solutions, spin angular momentum of the Dirac particle, The non-relativistic limit of Dirac equation, Electron in electromagnetic fields, spin magnetic moment, spin-orbit interaction, Dirac equation for a particle in a central field, fine structure of hydrogen atom.

Books Recommended:

1. Sakurai J.J. "Modern Quantum Mechanics", Pearson Education Pvt. Ltd., New Delhi, 2002.
2. Mathew P.M. and Venkatesan K. "A Text Book of Quantum Mechanics", Tata McGraw-Hill Publishing Company, New Delhi, 1981.
3. Khanna M.P. "Quantum Mechanics", Har Anand, New Delhi, 1996.
4. Thankappan V.K. "Quantum Mechanics", Wiley Estern, New Delhi, 1985.
5. Mandel H. and Shaw G. "Quantum Field theory", Wiley Eastern, New Delhi, 1984.

PHY -522 Numerical Methods and computational Techniques

Programming: Representation of constant and variables and functions, arithmetic expressions and their evaluation. Assignment statements, Logical constants variables and expression, control structures, input and output statements, Plotting graphs, sequencing alternation, arrays, Manipulating vectors and matrices, Subroutines, I/O Statements

Roots of Equations: Non-linear equation: Approximate values of roots, Bisection Method, Regula-Falsi Method, Newton-Raphson method, Bairstow Method, Solution of set of non-linear equations. Solution of Simultaneous Linear equation: Direct Method: Gauss elimination, Pivoting, Gauss-Jordon method, Matrix inversion. Iterative methods: Jacobi iteration method, Gauss Seidel iteration method.

Interpolation: Interpolation, Newton's formula for forward and backward interpolation, Divided difference, Symmetry of divided differences, Newton's general interpolation formula, Lagrange's interpolation formula, Cubic splines, Least square approximation, Interpolation in multidimension.

Numerical Differentiation and Integration: Derivatives using forward and backward difference formula Numerical integration, A general quadrature formula for equidistant ordinates, Trapezoidal rule, Simpson's rule, Weddle's rule, Romberg integration, Gauss quadrature formula, multiple integrals.

Differential Equation: Ordinary differential equation: Euler's method, Modified Euler's method, Runge-Kutta Method, system of coupled first order ordinary differential equations. Partial differential equations: An elementary idea about numerical solution of partial differential equations using finite difference method.

Books Recommended:

1. Rajaraman V. "Computer Programming in Fortran-90 and 95", Prentice Hall of India Ltd., New Delhi.
2. Stephen J. Chapman," Fortran 90/95 for Scientists and Engineers", McGraw Hill Education
3. William Press, "Numerical Recipes in Fortran", Cambridge University Press India Pvt Ltd.
4. Joe D. Hoffman, "Numerical methods for scientist and engineers", Marcel Dekker Inc,

New York
5. Steven C Chapra, Raymond P Canale "Numerical Methods for Engineers", Tata McGraw-Hill Education
6. Srimanta Pal "Numerical Methods: Principles, Analysis, And Algorithms", Oxford University Press
7. Scarbrough James B "Numerical Mathematical Analysis", Oxford and IBH Publishing Company, New Delhi, (1966).
8. Conte S.D. "Elementary Numerical Analysis", Tata McGraw Hill Publishing Company, New Delhi.

PHY -523 Thermodynamics and Statistical Physics

Review of Thermodynamics: Extensive and intensive variables, Laws of thermodynamics and their consequences, Thermodynamic potentials, Maxwell's thermodynamical relations

Classical Statistical Mechanics: The macroscopic and microscopic states, Postulate of equal a priori probability, contact between statistics and thermodynamics, classical ideal gas, Gibbs' paradox, phase space and Liouville's theorem and its consequences, Microcanonical, canonical, and grand canonical ensembles, partition functions, fluctuation of energy and density, Equipartition and virial theorems, Derivation of thermodynamic properties; some examples including (i) Classical ideal gas (ii) system of classical harmonic oscillators

Quantum Statistical Mechanics: Quantum-mechanical ensemble theory: Density matrix, simple applications of density matrix. Symmetric and Antisymmetric Wavefunctions. Microcanonical ensemble of ideal Bose, Fermi and Boltzmann gases. Statistics of the occupation numbers

Ideal Bose and Fermi Systems: Thermodynamic behaviour of an ideal Bose gas, Bose-Einstein condensation, Blackbody radiation and Plancks law of radiation, Thermodynamic behaviour of an ideal Fermi gas, Magnetic behavior of an ideal Fermi gas, Pauli paramagnetism

Phase Transition and critical phenomenon: First and second order phase transitions, Ising model, Critical exponents, Landau theory of phase transitions.

Books Recommended:

1. Patharia R.K. "Statistical Mechanics", Pergamon, Oxford.
2. Kerson Huang "Statistical Mechanics", Wiley Eastern, New Delhi.
3. Kittel C. "Elementary Statistical Physics", Wiley Eastern, New Delhi.
4. Agarwal B.K. and Eisner M "Statistical Mechanics", Wiley Eastern, New Delhi.
5. Chandler D. "Introduction to Modern Statistical Mechanics", Oxford University Press, New Delhi.

PHY -524 Solid State Physics

Crystal structure and binding in solids: Bravais lattice, lattice planes and miller indices, reciprocal lattice, Diffraction conditions, Brillouin zones, Atomic Structure factor; types of crystal binding, cohesive energy of ionic crystals.

Defects and Diffusion in solids Point defects: Schottky and Frenkel vacancies, Diffusion, Fick's law. Color centers, *F*-centers. Line defects (dislocation): Edge and Screw dislocation, Burger's vector, Slip, Planar (stacking) faults: Grain boundaries: Low angle grain boundaries.

Elastic Properties Introduction, Analysis of Stress- strain relations, Elastic Compliance and Stiffness Constants, Elastic Waves in Cubic Crystals.

Thermal Properties: Phonon heat capacity, Density of states, Debye and Einstein theory of specific heat, Lattice Thermal Conductivity and Umklapp Processes, specific heat of metals.

Semiconductors: Direct and Indirect Absorption Processes, Equations of motion, effective mass, intrinsic carrier concentration, impurity conductivity, Cyclotron resonance and Magnetoresistance in semiconductors.

Fermi Surfaces and Metals: Zone schemes, Fermi surfaces; Hall Effect, Electron, Hole and Open orbits, Quantization of orbits in a magnetic field, the de Hass-van Alphen Effect, External orbits.

Dielectrics: Macroscopic field, The local field, Lorentz field, The Claussius- Mossotti relation, different contributions to polarization: dipolar, electronic and ionic polarizabilities.

Books Recommended:

1. Kittle C "Introduction to Solid State Physics", John Wiley & Sons, 2005.
2. Dekkar A J "Solid State Physics", Macmillan India Ltd., New Delhi, 2004.
3. Azaroff L V "Introduction to Solids", Tata McGraw-Hill Publishing Company, New Delhi, 1992.
4. Ashcroft N W and Mermin N D "Solid State Physics", Thomson Asia Pte. Ltd., 2006.
5. Singh, R.J., Solid State Physics, Pearson, Press, 2012.

PHY-529 LABORATORY -II

The Lab will be twice in a week, each of three hours duration. Students will perform at least twelve experiments in this lab session.

SEMESTER III

PHY-531 Electronics

Electronic Devices: MESFETs and MOSFETs, Unijunction transistor (UJT), Four layer (PNPN) devices, Construction and working of PNPN diode, Semiconductor controlled rectifier (SCR) and Thyristor.
Electronic Circuits: Multivibrators (Bistable, Monostable, Astable), Differential amplifier, Operational amplifier (OP-AMP), OP-AMP as inverting, Non-inverting, Scalar, Summer, Integrator, Differentiator, Schmitt trigger and Logarithmic amplifier, Electronic analog computation circuit. A/D and D/A convertors, applications. Transducers
Communication Systems: Basic concepts of communication systems, Need for modulation, Information in communication system, Coding, Types of Pulse modulation, Pulse width modulation (PWM), Pulse position Modulation (PPM), Principle of Pulse code modulation (PCM).
Books Recommended:
1. Millman and Halkias "Electronic Devices and circuits"
2. Streetman Ben G and Banerjee "Solid State Electronic Devices", 5th Ed., Prentice Hall of India Ltd, New Delhi, 2004.
3. Sze S M. "Physics of Semiconductors Devices", John Wiley and sons, New Delhi.
4. George Kennedy "Electronic Communication Systems", 3rd Ed., Tata McGraw Hill Publishing Company, New Delhi, 1984.
5. Liao S.Y. "Microwave Devices and Circuits", Prentice Hall of India, New Delhi, 1995.
6. Mithal G.K. "Electronic Devices and Circuits", Khanna Publishers, Delhi, 1998.

PHY-532 High Energy Physics

Introduction and Overview: Historical development, Particle classification: Bosons, Fermions, Particles and Antiparticles, Quarks and Leptons; Basic ideas about the interactions and fields in Particle Physics, Types of interactions: Electromagnetic, Weak, Strong and Gravitational, Natural System of Units in High Energy Physics.

Invariance Principles and Conservation laws: Conservation of electric charge, Baryon number, Lepton number, Continuous symmetry transformations: translation and rotation; Parity, Pion parity, Charge conjugation, Strangeness and Isospin, Two Nucleon System, Pion-Nucleon System, G-parity, Time reversal invariance, Associated production of particles and Gell-Mann Nishijima scheme, $K0-K0$ doublet, CP violation in K- decay, CPT theorem.

Electromagnetic Interactions. Form factors of nucleons. Parton model and Deep inelastic scattering structure functions, Cross Section and Decay Rates.

QCD and Quark model: Asymptotic freedom and Infrared slavery, confinement hypothesis. Classification of hadrons by flavor symmetry : SU(2) and SU(3) multiplets of Mesons and Baryons. The Baryon Octet and Decuplet, Pseudoscalar mesons and Vector mesons.

Weak interactions: Classification of weak processes, Fermi theory of □- decay, Parity non conservation in □ - decay, two component theory of neutrino and determination of helicity, V-A interaction, Strangeness changing and non-changing decays, Cabibbo's theory.

Gauge invariance and Unification schemes: Global and Local invariance of the Action, Noether's theorem, Spontaneous breaking of symmetry and Goldstone theorem. Abelian and Non-Abelian gauge fields.

Books Recommended:

1. Introduction to High Energy Physics, D.H. Perkins.
2. Introduction to Particle Physics, M.P. Khanna.
3. Introduction to Elementary Particles, D. Griffiths.
4. Particle Physics, Martin and Shaw.
5. Introduction to Quarks and Partons, F.E. Close
6. Quarks and Leptons: An Introductory Course in Modern Particle Physics, F. Halzen and A.D. Martin.

PHY-538 LABORATORY III

The Lab will be twice in a week, each of three hours duration. Students will perform at least twelve experiments in this lab session.

SEMESTER IV

PHY-541 Nuclear Physics

Nuclear Properties: Introduction, constituents of nucleus and their intrinsic properties, angular momentum, magnetic moment and electric quadrupole moment of nucleus, wave mechanical properties of nucleus, nuclear forces

Nuclear Interactions: Nuclear force: Two nucleon system**,** deuteron problem, binding energy, nuclear potential well, pp and pn scattering experiments at low energy, meson theory of nuclear force, e.g. Bartlett, Heisenberg, Majorana forces and potentials, exchange forces and tensor forces, effective range theory-spin dependence of nuclear force, Charge independence and charge symmetry of nuclear forces-Isospin formalisim, Yukawa interaction

Nuclear Models: Liquid drop model, Bohr-Wheeler theory of fission, Experimental evidence for shell effects, Shell Model, Spin-Orbit coupling, Magic numbers, Applications of Shell model like Angular momenta and parities of nuclear ground states, Quantitative discussion and estimates of transition rates, magnetic moments and Schmidt lines, Collective model-nuclear vibrations spectra and rotational spectra

Nuclear Decay: Beta decay, Fermi theory of beta decay, shape of the beta spectrum, Total decay rate, Angular momentum and parity selection rules, Comparative half-lives, Allowed and forbidden transitions, selection rules, parity violation, Two component of neutrino decay, Detection and properties of neutrino, Gamma decay, Multipole transitions in nuclei, Angular momentum and parity selection rules, Internal conversion, Nuclear isomerism.

Nuclear Reaction: Conservation laws, energetics of nuclear reaction, Direct and compound nuclear reaction mechanism, Compound nuclear-scattering matrix, Reciprocity theorem, Breit Wigner one level formula, Resonance scattering.

Books Recommended:

1. Bohr A. and Mottelson B.R. "Nuclear Structure", Vol. 1 (1969) and Vol.2 (1975), Benjamin, Readings, A.
2. Krane K. S. "Introductory Nuclear Physics", Wiley Estern, New York, 1988.
3. Roy R.R. & Nigam B.P. "Nuclear Physics", New Age International, New Delhi.
4. Irving Kaplan "Nuclear Physics", Addison Wesley, New Delhi.
5. Pal M. K. "Theory of Nuclear Structure", East West Press Pvt. Ltd., New Delhi.
6. Hans H.S. "Nuclear Physics: Experimental and Theory", New Age International, New Delhi, 2001.

Elective –I

PHY-525 Experimental Techniques in Physics

Unit-I Optical Microscopy; Scanning Electron Microscopy; Scanning Tunneling Microscopy; Atomic Force Microscopy; X-ray diffraction, Mass Spectrometry, Thermal Characterization.

Unit-II Transmission Electron Microscopy; Low Energy Electron Diffraction; Reflection of High Energy Electron Diffraction; Neutron diffraction; Electron Spectroscopy for chemical analysis; Auger Electron Microscopy; Secondary ion mass spectroscopy; Electron Energy Loss Spectroscopy, Molecular spectroscopies including Microwave, FTIR, Raman and surface enhanced Raman Spectroscopy.

Unit-III X-ray Fluorescence; Rutherford back scattering; UV-VIS-NIR spectro-photometer & Ellipsometry; Deep Level Transient Spectroscopy; Thermally Simulated Current; C-V and Admittance Spectroscopy; Hall effect and Time of Flight methods for charge carriers, Differential scanning calorimeter; Differential Thermal Analyzer.

Books Recommended:

1. Sayer, M., Mansingh, A., Measurement, Instrumentation and Experiment Design in Physics and Engineering, PHI (2000).
2 Nanotechnology - Molecularly Designed Materials : G.M. Chow & K.E. Gonsalves

(American Chemical Society), 1996.
3 Nanotechnology Molecular Speculations on Global Abundance : B.C. Crandall (MIT Press), 1996.
4 Nanoparticles and Nanostructured Films–Preparation, Characterization and Application: J.H. Fendler (Wiley), 1998.

PHY-526 Polymer & Liquid Crystals

Polymer: Introduction, monomer, degree of polymerizations, chemistry of polymers, polymer synthesis and polymer structure, polymers classification's, polymer morphology, thermal properties, multicomponent polymeric materials, applications.

Liquid Crystals: Classification of liquid crystals: Thermotropic and lyotropic, Nematic, Smectic, cholestric, Ferroelectric liquid crystals (LCs), Blue phase LCs, molecular structure of LCs, structure- property relationship of thermotropic liquid crystals. Molecular and mean field theory,Birefringence phenomena, polarizing microscopy, texture identifications and defects, Electric & Magnetic effects, Optical properties of liquid crystals. Liquid crystal composites:polymer and nano-materials dispersed liquid crystals composites, polymer liquid crystals, molecular dynamics between LCs and Dopants.Liquid crystal applications: present and future displays, manufacturing of LCDs, twisted nematic, super-twisted nematic, LED, IPS based displays and overview of LC in advance field's.

Books Recommended:

1. Introduction to Liquid crystal Chemistry and Physics: Peter J. Cooling and M. Hird, Taylor and Francis, (1997).
2. The physics of Liquid Crystals, P.G. De. Gennes, Oxford University Press, (1993).
3. Liquid Crystals, 2nd edition, S. Chandrasekhar, Cambridge University Press, (1992).
4. Liquid Crystal fundamental, S. Singh, D. A. Dunmur, World Scientific, (2002)
5. Handbook of Polymer Science and Technology, M. H. Ferry, CBS, Vol. 2 (2012)
6. Polymer Science, Gowarikar, Johan wiley and Sons, (1986)
7. Principles of Polymer Science, Bahadur and Sastry, Narosa Publishing House,(2002).

PHY-527 Nanostructured Materials

Introduction to Nanomaterials: Types of Nanomaterials, Emergence and challenges in nanotechnology, Properties of Nanomaterials, role of size in Nanomaterials, nanoparticles, nanowires, nanoclusters, quantum wells, conductivity and enhanced catalytic activity compared to the same materials in the macroscopic state, Properties of Nanomaterials: Stability of Nanomaterials, Mechanical properties, Optical, Electrical and Magnetic properties, nano-diffusion.

Fabrication of Nanomaterials: Synthesis routes for nanomaterials: Bottom-up and top-down approaches, Solid, Liquid, Gas phase synthesis, Hybrid Phase synthesis, Synthesis of bulk Nanostructured materials: Approaches and challenges.

Characterization techniques of nanomaterials : Characterization of Nanostructures: Structural Characterization X-ray diffraction, Small angle X-ray Scattering, Optical Microscope and their description, Scanning Electron Microscopy (SEM), Scanning Probe Microscopy (SPM), TEM and EDAX analysis, Scanning Tunneling Microscopy (STM), Atomic force Microscopy (AFM). Thermal Characterization of Materials: DTA, TGA, DSC (Principle and Applications).
Future Applications: MEMs, Nanomachines, Nanodevices, quantum computers, Opto-electronic devices, quantum electronic devices, Environmental and Biological applications.

Nanocomposites: An Introduction: Types of Nanocomposite (i.e. metal oxide, ceramic, glass and polymer based); Core-Shell structured Nanocomposites, Superhard Nanocomposite, Mechanical Properties, Modulus and the Load-Carrying Capability of Nanofillers, Failure Stress and Strain Toughness, Glass Transition and Relaxation Behavior, Abrasion and Wear Resistance, Permeability, Dimensional Stability Contents, Thermal Stability and Flammability, Electrical and Optical Properties, Resistivity, Permittivity, and Breakdown Strength, Refractive Index, Light-Emitting Devices.

Books Recommended:

1. Nanostructures and Nanomaterials; Synthesis, Properties and Applications Guozhong Cao Imperial College Press
2. Introduction to Nanotechnology Chales P Poole, Frank J Owen, Wiley India
3. Handbook on Nanotechnology Vol 5 H S Nalwa
4. Nanostructures :- Fabrication and analysis, Springer
5. Nano: The Essentials, Understanding Nanoscience and Nanotechnology, T Pradeep, McGraw Hill

Elective -II

PHY-533 OPTO-ELECTRONICS

Introduction : Light, elements of solid state physics, modulation of light, Review of energy bands, effective mass, Fermi level, classification of semiconductors into element, binary, ternary and quaternary compounds, conduction mechanisms, amorphous semiconductors. Contact potential explanation based on band structure, M-S contact and its properties, barrier layer, P-N junction, potential barrier and barrier width, forward and reverse saturation current junction capacitance.

Processing of Semiconductor Materials: Purification, Zone refining and zone floating methods, Epitaxial growth methods, liquid phase, vapour phase and molecular beam epitaxy. Introduction of impurities, junction,successive doping method, epitaxial and diffusion methods, MESA and planar structure doping of amorphous semiconductors.

Displays devices and photo detectors: Luminescence from quantum well, photo luminescence and phosphorescence, phototransistors electro luminescence process, LED's their structures and choice of materials, Plasma displays, liquid crystal displays Introduction, thermal detector, photon devices and their characteristics, solar cells, photomultimeter

Laser: Emission and absorption of radiation, population inversion, pumping, doped laser, gas laser, semiconductor laser, liquid dye laser, laser modes and holography

Books Recommended:

1. S.M.Sze, "Physics of Semiconductor Devices", 2nd Ed., Wiley, New York,2000.
2. P.Bhattacharya, "Semiconductor Opto-electronic Devices", PHI, 1996.
3. J.Wilson & J.F.B.Hawkes, "Optoelectronics", PHI, 1998.
4. S.S. Islam, "Semiconductor Physics and Devices", Oxford University Press, 2005.
5. A. K. Ghatak & K Thyagarajan, "Optical Electronics", Cambridge University Press, 1989.

PHY-534 Microwave Electronics

Introduction: Microwaves and its frequenc y spectrum, Application of microwaves, Waveguides - Rectangular wave guides, Circular wave guide, Wave equations & their solutions, TE, TM & TEM modes. Attenuation - Cause of attenuation in wave guides, wall current & derivation of attenuation constant, Q of the wave guide. Resonators - Resonant Modes of rectangular and cylindrical cavity resonators, Q of the cavity resonators, Excitation techniques, Introduction to Microstrip and Dielectric resonators. Microwave propagation in ferrites, Faraday rotation, Devices employing Faraday rotation (isolator,Gyrator,Circulator). Introduction to single crystal ferromagnetic resonators, YIG tuned solid state resonators.

Microwave tubes: Spacecharge spreading of an electron beam, Beam focusing, Klystrons - Velocity Modulation, Two Cavity Klystron, Reflex Klystron, Efficiency of Klystrons. Magnetrons - Modes of oscillation & operating characteristics, Traveling wave tubes.

Devices: Avalanche Transit Time Device - Read Diode, Negative resistance of an avalanching p-n Junction diode, IMPATT and TRAPATT, Transferred Electron Device - Gunn effect, two valley model, Different Modes for Microwave generation, Passive Devices - Termination (Short circuit and matched terminations) Attenuator, Phase changers, Tees, Hybrid Junctions, Directional coupler.

Parametric Amplifier: Varactor, Equation of Capacitance in Linearly graded & abrupt p-n junction, Parametric upconvertor, Negative resistance parametric amplifier, Noise in parametric amplifiers.

Microwave Antennas: Introduction to antenna parameters, Potential functions, Radiation from a aperture antenna, Electromagnetic Horns, Prabolic reflectors, Microstrip antenna, Introduction to antenna arrays.

Books Recommended:

1. Jorden & Balmain, "Electromagnetic waves & Radiating Systems", PHI, 1993.
2. Atwater, "Introduction to Microwave Theory", McGraw Hill, 1962.
3. M.L. Sisodia and G.S. Raghuvanshi, "Microwave Circuits & Passive Devices", New Age International, 1988.
4. R. E. Collin, "Foundations of Microwave Engineering", McGraw Hill, 2001.
5. H.A. Watson, "Microwave Semiconductor Devices and Their Circuit Applications", 1969.
6. C.A. Balanis, "Antenna Theory", Harper & Row. Pub. & Inc., New York, 1997.
7. S.Y.Liao, "Microwave Devices & Circuits", PHI.
8. H.J. Reich, "Microwave Principles", PHI, 1990.

PHY-535 Plasma Physics

Basics of Plasmas: Occurrence of Plasma in nature, Definition of plasma, Concept of temperature, Debey shielding and plasma parameter, Single particle motions in uniform E and B fields, Non monuniform magnetic field, grad – B drift and curvature drift, Magnetic mirror. Simple applications of plasmas.

Plasma Waves : Plasma oscillations, Electron plasma waves, Ion waves, Electrostatic electron and ion oscillations perpendicular to magnetic field, Upper hybrid waves, Lower hybrid waves, ion cyclotron waves, Light waves in plasma.

Non-linear Effects in Plasma: Introduction, Ponderomotive force, Parametric Instabilities: Coupled Oscillators, Frequency matching, Instability Threshold, Oscillating two-stream instability.

Nuclear Fusion: Introduction, Lawson criteria, Fundamentals of inertial confinement fusion, Fundamentals of magnetic confinement method, Tokamak, Hydrodynamics of implosion.

Books Recommended:

1. Chen F F “Introduction to Plasma Physics and Controlled Fusion”, Plenum Press, New York, 1980.
2. Krall N.A. and Trivelpiece A.W. “Principle of Plasma Physics”, Tata McGraw- Hill Publishing Company, New Delhi, 1972.
3. Dendy R “Plasma Physics”, Cambridge University Press, New York, 1996.
4. Friedberg J P “Ideal Magnetohydrodynamics”
5. Seshadri S R “Fundamental of Plasma Physics”,
6. Chanchal Uberoi “Introduction to Unmagnetized Plasma”, Prentice Hall of India Pvt. Ltd., New Delhi, 1997

Elective –III

PHY- 542 Nuclear Accelerator and Radiation Physics

Detection of Nuclear Radiations and their measurements: Methods for detection of free change carriers, Ionization chamber, Proportional counter, Geiger-Muller counter, Semiconductor detectors, Scintillation detector, Cheremkov detector, Wilson cloud chamber, Bubble chamber, Spark chamber, Nuclear emulsion techniques, Solid State nuclear track detector.

Determination of Nuclear Properties: Nuclear mass measurement, Ion optics, Production and detection of positive ions, Dempster's mass spectrometer, Aston's and Bainbridge's mass spectrograph, Double focusing mass spectroscope, Measurement of nuclear spin and magnetic moment, Nuclear spin from Zeeman effect of hyper fine lines, Nuclear spin and statistics from molecular spectra, Atomic beam method of nuclear magnetic moment determination, Magnetic resonance absorption method, Nuclear induction and microwave spectroscopy method.

Accelerators of Charged Particles: Classification and performance characteristics of accelerators, Ion sources, Electrostatics accelerators, Cockroft – Walton generator, Cyclotron, Synchro-cyclrotron, Betatron, Electron and proton synchrotron, Microtron, Linear accelerator.

Neutrons and Neutron Physics: Classification and properties of neutron, Sources of neutron, Neutron detectors; Slow neutron detection through nuclear reactions and induced radioactivity, Fast neutron detection, Neutron monochromators, Diffusion of thermal neutron.

Books Recommended:

1. Lapp R E and Andrews H L "Nuclear Radiation Physics", Fourth edition, Prentice Hall, New Delhi, 1963.
2. Mc Dowell C A "Mass spectroscopy", McGraw Hill Book Company, New Delhi, 1963.
3. Segre E "Experimental Nuclear Physics", John Wiley and Sons, 1953.
4. Livingstone M.S. and Blewett J P "Particle Accelerators", McGraw Hill Book Co., 1962.
5. Kapoor S S and Ramamurthy V S "Nuclear Radiation Detectors" Wiley Eastern, New Delhi, 1986.
6. Glasstone S "Principles of Nuclear Reactor Engineering", Mc Millan Co. London, 1956.
7. Ghoshal S N "Nuclear Physics", S Chand and Co., New Delhi, 2006.

PHY- 543 Nuclear Instrumentation

General: Introduction to Properties of Nuclear Systems & Radiation, Interaction of radiation with matter, radioactive sources- choice of isotopes.

Radiation detectors- Radioactivity and matter: Nuclear properties; Radiation detection and measurement. Ionization chamber, Geiger Muller counters, Scintillation counters, Semi conductor devices, Neutron detectors based on recoil measuring circuits including modulators; converters& stabilizers, Synchronous detectors. Nuclear techniques and analytical instruments, X.R.F techniques, Industrial instruments, density estimation of the fluids, Medical instrumentation, thyroid estimation, CT, MRI. Gamma Ray Spectroscopy Technique.

Safety: Hazards of ionization radiation, physiological effect of radiation, dose and risk radiological protection (alpha, beta and gamma, X, neutron)-shielding material and effectiveness. Operational safety instrument, emergency schemes, effluent disposal, application to medical diagnosis and treatment. Effects of Ionising Radiations, Induction of cancers, Risk Assessments, Risk factors for cancers, Hereditary disease, Communal risk, Other late effects, Irradiation in pregnancy, System of Radiological Protection, Central principles, Scope of application, Justification of practices, Optimisation of protection, Limitations of doses, Constraints, Comparing risks, Legal controls.

BOOKS RECOMMENDED:

1. Vashtell, C.C ,S.G Hewit Nucleonic instrumentation, Newnes,(1965).
2. Michael Sayer and Abhai Mansingh, Measurement, Instruments and Experimental Design in Physics and Engineering, PHI, (2000).
3. Glen F. Knoll, Radiation Detection and Measurement, 4th Edition, Wiley Science, (2010).
4. Modern Physics by G. Aruldhas and P. Rajgopal, Publisher: PHI.

PHY- 544 Quantum Field Theory

Canonical Quantization: Resume of Lagrangian and Hamiltonian formalism of a classical field, Second quantization: Concepts and illustrations with Schrodinger field.
Klein Gordan Field: Quantization of a real scalar field and its application to one meson exchange potential, Quantization of a complex scalar field.
Dirac Field: The Dirac Equation, Relativistic Covariance. Anti-Commutators, Quantization of the Dirac Field, Electrons and Positrons.
Gauge Field: Gauge Invariance and Gauge Fixing. Quantization of the Electromagnetic Field, Propagator, Vacuum Fluctuations.
Interacting Theory and Elementary Processes: Feynman diagrams and their applications, Lowest Order Cross-Section for Electron-Electron, Electron-Positron and Electron-Photon Scattering, Wick's Theorem, Scattering matrix and Higher order corrections.

Books Recommended:

1. Quantum Field Theory, C. Itzykson and J. B. Zuber, McGraw-Hill Book Co, 1985.
2. Quantum Field Theory, L. H. Ryder, Cambridge University Press, 2008.
3. Field Theory, A Modern Primer, P. Ramond, Benjamin, 1980.
4. The Quantum Theory of Fields, Vol I, S. Weinberg, Cambridge University Press, 1996.
5. Introduction to The Theory of Quantum Fields, N. N. Bogoliubov and D. V. Shirkov, Interscience, 1960.
6. An Introduction to Quantum Field Theory, M. E. Peskin and D. V. Schroeder, Westview Press, 1995.