Course Structure

for

PHYSICS (M.Sc.)

A Four Semesters Course (CBCS)

(With effect from 2020-2021 academic session)

COOCHBEHAR PANCHANAN BARMA UNIVERSITY

COOCH BEHAR

WEST BENGAL

COOCH BEHAR PANCHANAN BARMA UNIVERSITY
M.Sc. (Physics) CURRICULUM

M.Sc. in Physics

There will be four semesters. The Curriculum consists of 11 Core Courses (Core 1-11), 3 Discipline Centric Elective (DCE 1-3) Courses and 2 Generic Elective (GE 1-2) Courses. Each course is of 100 marks i.e., 5 credits.

SCHEME FOR CHOICE BASED CREDIT SYSTEM

Semester	CORE COURSE (11)	Discipline Centric Elective DCE (3)	Generic Elective GE (2)
I	**Core-1** (5 credit)		
	Core-2 (5 credit)		
	Core-3 (5 credit)		
	Core-4 (5 credit)		
II	**Core-5** (5 credit)		
	Core-6 (5 credit)		
	Core-7 (5 credit)		
	Core-8 (5 credit)		
III	**Core-9** (5 credit)		**GE-1** (5 credit)
	Core-10 (5 credit)		
	Core-11 (5 credit)		
IV		**DCE-1** Special Paper I: (5 credit)	**GE-2** (5 credit)
		DCE-2 Special Paper II: (5 credit)	
		DCE-3 Special Paper III: (5 credit)	

SEMESTER	COURSE OPTED	COURSE NAME	Credits
I	Core course-1	Mathematical Methods in Physics	5
	Core course-2	Classical Mechanics & Special Relativity	5
	Core Course-3	Electronics I	5
	Core Course-4	Computational Methods, Programming, Laboratory Course I (Electronics)	5
II	Core course-5	Condensed Matter Physics I	5
	Core Course-6	Statistical Mechanics	5
	Core course-7	Quantum Mechanics	5
	Core Course-8	Laboratory Course II	5
III	Core course-9	Electrodynamics & Plasma Physics	5
	Core Course-10	Atomic and Molecular Physics	5
	Core course-11	Nuclear and Particle Physics I	5
	GE-1	Advanced Laboratory Course III (Programming)	5
IV	DCE-1	Astro-particle physics/Nuclear Physics and Particle Physics II/Electronics II/Solid State Physics II (**one course from the cluster**)	5
	DCE-2	Cosmology/ Nuclear Physics and Particle Physics III/Electronics III/Solid State Physics III (**one course from the cluster**)	5
	DCE-3	Laboratory Course IV (based on DCE-1 and DCE-2 courses) and Project	5
	GE-2	Quantum Mechanics II/General Relativity/ Physics of Quark & Gluon/ Laser Physics/ Spectroscopy (**two courses from the cluster**)	5
Total Credits			80

Semester wise distribution of Marks

Semester-I

Sl. No.	Paper	Written	Continuous evaluation	Attendance	-	-	Total	Credit
1.	Core-1	75	20	05	-	-	100	05
2.	Core-2	75	20	05	-	-	100	05
3.	Core-3	75	20	05	-	-	100	05
Sl. No.	**Paper**	**Practical**		**Attendance**	**-**	**Programming**	**Total**	**Credit**
4	Core-4	50	20	05	-	25	100	05

Semester-II

Sl. No.	Paper	Written	Continuous evaluation	Attendance	-	-	Total	Credit
1.	Core-5	75	20	05	-	-	100	05
2.	Core-6	75	20	05	-	-	100	05
3.	Core-7	75	20	05	-	-	100	05
Sl. No.	**Paper**	**Practical**		**Attendance**	**-**		**Total**	**Credit**
4.	Core-8	75	20	05	-	-	100	05

Semester-III

Sl. No.	Paper	Written	Continuous evaluation	Attendance	-	-	Total	Credit
1.	Core-9	75	20	05	-	-	100	05
2.	Core-10	75	20	05	-	-	100	05
3.	Core-11	75	20	05	-	-	100	05
Sl. No.	**Paper**	**Practical**	**Continuous evaluation**	**Attendance**	**-**	**-**	**Total**	**Credit**
4.	GE-1	75	20	05	-	-	100	05

Semester-IV

Sl. No.	Paper	Written	Continuous evaluation	Attendance	-	-	Total	Credit
1.	DCE-1	75	20	05	-	-	100	05
2.	DCE-2	75	20	05	-	-	100	05
3.	DCE-3	**Practical 25**	**Continuous evaluation 20**	**Attendance 05**	**Project 50**	**-**	**100**	**05**
4.	GE-2	75	20	05	-	-	100	05

Semester-I

Core Course-01: Mathematical Methods in Physics

Complex analysis: Functions of complex variables, regular and singular points. Cauchy–Riemann equations, integration in the Complex plane, Analytic functions. Cauchy's theorem and consequences, integral formulae. Expansion of functions about regular and singular points. Proof of Taylor and Laurent expansions. Singular points and their classification. Residue theorem and its application in evaluating integrals and series summations. Liouville's theorem. Moretra's theorem. Branch Point and branch Cut. Riemann sheets. Integrals involving branch point singularity.

Partial differential equations and integral transforms: Fourier transforms. Inverse Fourier transforms. Fourier transform of derivatives. Convolution theorem. Momentum representation. Laplace transforms. Inverse Laplace transforms. Laplace transform of derivatives. Derivative of a transform. Integration of transforms. Laplace Convolution theorem. Solution of ordinary and partial differential equations by Fourier and Laplace transform methods.

Differential equations and special functions: Legendre, Bessel and Hermite differential equations. Dirac's delta function; Gamma and Beta functions; Legendre and associated Legendre polynomials.

Linear vector space and matrices: Definition of vector space; dimension, basis, subspace; inner product, orthogonality and completeness. Gram-Schmidt orthogonalisation procedure. ***Linear operators***: Representation of operators by matrices.

Matrices: Eigenvalues and eigenvectors of matrices. The Cayley-Hamilton theorem. Bilinear and Quadratic forms. Principal axis transformation. Functions of matrices. Powers of a matrix. Roots of a matrix. Exponential of a matrix. Logarithm of a matrix.

Tensor analysis: Coordinate transformations, Scalars, Covariant and Contra-variant and Mixed tensors. Addition, Subtraction, Outer, Inner product and Contraction. Symmetric and anti-symmetric tensors. Quotient law. Kronecker delta, Levi-civita symbol and metric tensors. Conjugate tensor. Length and angle between vectors. Associated tensors. Raising and lowering of indices. Tensor calculus. Differentiation of a tensor. The Christoffel symbols and their transformation laws. Covariant derivative of tensors.

Green's function: Non-homogeneous boundary value problem and Green's function, eigen function expansion of Green's function, Fourier transformation method of constructing Green's function, application to physical problems.

Group theory: Introduction, group multiplication table, discrete and continuous groups. Group representations: Faithful and Unfaithful representations, Reducible and Irreducible representation of groups, equivalent representation, representation by unitary matrices, Schur's lemma, orthogonality theorem. Rotation groups, unitary groups and Lorentz homogeneous groups. Rearrangement theorem; Isomorphism and homomorphism; Illustrations with point symmetry groups; Lie groups and Lie algebra with SU(2) as an example.

Books Recommended:

1. *M. R. Spiegel (Schaum's outline series) – Theory and Problems of Complex Variables.*
2. *George B. Arfken and Hans J. Weber (Academic Press) – Mathematical Methods for Physicists.*
3. *J. Mathews and R. I. Walker (Benjamin) – Mathematical Methods of Physics.*
4. *P. Dennery and A. Krzywicki (Harper and Row) – Mathematics for Physicists.*
5. *W. Joshi (Wiley Esstern) – Matrices and Tensors*

Core Course-02: *Classical Mechanics and Special relativity*

Lagrange's and Hamilton's Principle: Principle of virtual work and D' Alembert's principle; constraints, generalized coordinates and Lagrange's equation of motion. Elements of calculus of variation, applications; Hamilton's principle; principle of least action; Lagrange's equations for non-holonomic and dissipative systems; generalized momenta; phase space and configuration space; symmetry and conservation theorems.

Rigid body kinematics: Kinematics of rigid body motion; degrees of freedom; Euler angles; The Cayley-Klein parameters and spinors; infinitesimal rotation and pseudo vector; rotating frame and pseudo forces; torque free motion of a rigid body; heavy symmetrical top.

Hamilton's equations: Legendre transformation and derivation of Hamilton's canonical equations; derivation of canonical equations from a Variational principle; Routhian and Routh's procedure.

Canonical transformations: Equation of canonical transformation, generating functions, Lagrange and Poisson brackets (PB); canonical invariance of Poisson brackets; equation of motion in PB notation; infinitesimal canonical transformation and constants of motion, angular momentum PB relations; Liouville's theorem.

Hamilton Jacobi theory: H-J equation, separation of variables; Hamilton's principal and characteristic functions; action angle variables.

Small oscillations: Stable and unstable equilibria; small oscillations; the Eigen value equation and the principal axis transformation for oscillatory systems; frequencies of free vibration and normal co-ordinates; vibration of linear tri-atomic molecule.

Continuous systems: Transition from a discrete to a continuous system; Lagrangian formulation of continuous systems and fields; Hamiltonian formulation; applications.

Special relativity: Postulates of relativity and Lorentz transformations; kinematical consequences; covariant four dimensional formulations; Minkowski space and metric; relativistic momentum; mass energy equivalence; 3-force and Minkowski force; Lagrangian formulation of relativistic mechanics; covariant Lagrangian formulation.

Books Recommended:

1. *Classical mechanics-Goldstein*
2. *Introduction to advances dynamics-McCuskey*
3. *Mechanics- Landau and Liftshitz.*
4. *Classical Mechanics- K.C. Gupta*
5. *Classical Mechanics- Rana and Jog*
6. *Relativity-R Resnick*

Core Course-03: *Electronics I*

Transistors: JFET, BJT, MOSFET and MESFET- structure, working, derivation of the equations for I-V characteristics under different conditions. High-frequency limits. LED, UJT, SCR and other pn-pn devices, structure and working principle.

Basic small signal amplifiers: Classification of amplifiers, BJT/FET amplifier circuits, model and generalized amplifier circuits, Bootstrapped and Darlington amplifier circuit. Cascade amplifiers, Difference amplifiers, Multistage R-C coupled amplifiers. Noise in electronic circuits.

Feedback in amplifiers: General properties of feedback amplifiers, types of feedback and their effect on impedance levels. Practical feedback amplifiers using BJT, FET and OP-AMP. Audio power amplifiers. Audio power amplifier requirements, Class A, Class B and Class C power amplifiers, Push pull and tuned power amplifiers.

Oscillators: Feedback sinusoidal oscillator and condition of oscillation, Phase-shift oscillator, Wien bridge oscillator and Multivibrator using BJT / FET; ***OP AMP:*** Differential amplifiers, DC and AC analysis, CMRR, constant current bias level translator.

Practical OP AMP: Input offset voltage and current, input bias current, total output offset voltage, CMRR and frequency response. Mathematical Operations: DC and AC amplifier, circuits for summing, scaling, integrator and differentiator, log, antilog and other mathematical operations. Solution of second-order differential equations.

Special circuits using OP AMP:

Comparators, square wave and triangle wave generators, voltage regulators, fixed and adjustable voltage regulators, switching regulators, active filters.

Flip flops: RS latches, level clocking, edge-triggered D flip flops, edge-triggered JK flip flops, JK master-slave flip flops.

Combinational logic design: Standard representation for logical functions, Karnaugh map representation of logical functions, simplification of logical functions using K-map, minimization of logical functions specified in Minterms/Maxterms or truth table, Don't care conditions, X-OR and X-NOR simplification of K-maps, five and six variable K-maps.

Networks and lines: Mesh and node analysis, network impedances, network theorems. Resonant circuits, inductively coupled circuits, reflected impedance. Passive filter circuits. Elementary theory of transmission lines and wave guides.

Books Recommended:

1. ***J D Ryder, Electronics Fundamental and application, PHI***
2. ***Gaykwad, Operational Amplifier.***
3. ***Zee, Physics of semiconductor devices.***
4. ***Milman and Grable, Microelectronics. Tata MacGraw Hill.***
5. ***R P Jain, Modern digital electronics, Tata mac'Hill.***
6. ***J.D.Ryder, Networks line and fields.***

Core Course-04

A. *Computational Methods and Programming*

Approximations and errors in computing: Introduction; data errors; round off errors; truncation errors; modeling errors; significant digits; absolute and relative errors; general formula of errors; error estimation.

Interpolation: Newton's formulas; Lagrange's interpolation; inverse interpolation.

Numerical differentiation and integration: Numerical differentiation; numerical integration - Simpson's, Weddle's and trapezoidal rules; Gauss' quadrature formula; accuracy of quadrature formulas.

Solutions of algebraic and transcendental equations: Bisection method; method of regula falsi; Newton-Raphson method; secant method; method of iteration; simultaneous equations; roots of a polynomial; synthetic division method;.

Solutions of linear simultaneous equations: Gauss elimination method; Gauss-Jordan method; LV decomposition method; matrix inversion method; Round off errors and refinement; method of iteration.

Solution of differential equations: Euler's and Picard's methods; Milne's method; Runge – Kutta method; Multistep method; solution of second order differential equations.

Methods of least squares: Fitting of experimental data; least squares method; fitting of linear, polynomial and transcendental equations.

B. Laboratory Course I

(List of experiments should be regarded as suggestive of the standard and may not be strictly adhered to. New experiments of similar standard may be added and old experiments may be deleted whenever felt it necessary).

a. To design and construct a stabilized power supply (Constant Voltage Source) using discrete devices and to study the variation of load voltage with load current. Show also the variation of load voltage with load current using IC 78XX.

b. To design and construct constant – K type (a) low pass (b) high pass (c) band pass filters (using π section) and to study the variation of attenuation and phase constants of these filters with input frequency. To determine the cut off frequencies and to compare with theoretical values.

c. To study the variation of output voltage with frequency and load resistance for a given class-B Push Pull amplifier and to obtain the variation of output power with frequency and load resistance.

d. To design and construct clipping and clamping circuits using diodes and to study the variation of output amplitude and wave form using CRO.

e. To design an astable multivibrator using BJT and to study its output waveform and frequency for various RC values. To study how the output can be converted to a square wave using clipping circuit.

f. To design a Uni-junction Transistor circuit and draw its characteristic curves for different values of supply voltage. Use it as a saw - tooth wave generator and determine the frequency of oscillation.

g. To design a circuit diagram and study the voltage gain, input impedance, and power gain of an emitter follower.

h. To study the artificial transmission line (TL) at low frequency (<<1kHz) and to determine the line parameters of the given TL. To construct using OPAMP, (i) Differentiator (ii) Integrator (iii) adder-subtractor circuits. To study their performance for different time varying inputs.

i. To determine CMRR, input offset voltage, output offset voltage, input bias current and slew rate of an OP- AMP.

j. To study OP-AMP as voltage comparator. Plot a curve in input and output voltages and show how the output switches from positive to negative value.

k. To design and construct a Wein-Bridge oscillator using OPAMP and to study its output waveform and frequency for various RC values.

l. To study OP-AMP as a function generator, i.e. as (a). square wave generator (b). triangular wave generator.

m. To construct Half-Adder and Full-Adder circuits using logic gates and to perform some simple 2's complement Adder-Subtractor operations (Two decimal digits).

n. To construct X-OR gate using NAND gates and to verify truth table.

    i. To convert two inputs NAND gate to two input OR gate.
    ii. To construct NOR gate by using other gates and hence verify the truth table.

Semester-II

Core Course-05: Condensed Matter Physics I

Elementary crystallography: Crystal lattice & symmetry; unit cell; Bravais lattices; Miller indices; Bragg's law; Laue diffraction; reciprocal lattice; simple crystal structures x-ray diffraction; Bragg's law; atomic scattering factor; crystal structure factor, neutron diffraction; electron diffraction.

Crystal binding: Different types of binding; simple theory of ionic crystals; van der Wall's interaction.

Dielectric Properties of insulators; Static dielectric constant: complex dielectric constant; dielectric loss; classical theory of electric polarization; ferro-electricity.

Lattice vibrations: Vibrations monatomic and diatomic chains; acoustical and optical lattice vibrations in crystals; dispersion relation; an-harmonic vibrations and thermal expansion.

Free electron Fermi gas: Classical free electron theory; its failures; Fermi-Dirac probability distribution function; periodic boundary conditions in a solid; density of states; Fermi energy- its dependence upon temperature; electronic specific heat of solid; Para-magnetism of free electrons.

Band theory: Bloch theorem; motion of electrons in a periodic lattice; Brillouin zones for simple lattices; crystal momentum; effective mass; nearly free electron approximation; tight binding approximation; application to simple cubic lattices; ideas of Fermi surfaces; band structure of simple elements.

Magnetic properties of solids: Diamagnetism; paramagnetic susceptibility; behavior of the rare earths and the iron group of metals; Hund's rules; ferromagnetism; classical theory; Weiss' theory; Heisenberg exchange energy; domain structure; elementary ideas of ferri- and anti-ferro magnetism; Neel temperature.

Semiconductors and their properties: Intrinsic and extrinsic semiconductors; mechanism of conduction in semiconductors; motion of hole-electron pair-carrier transport equation, Hall effect.

Superconductivity: Properties of super conductors, type I and II super conductors; super conducting magnets; Meissner effect; London's equations; electron tunneling; Josephson effect.

Books recommended:

1. ***F.C.Phillips: An introduction to crystallography (wiley)(3rd edition)***
2. ***Charles A Wert and Robb M Thonson: Physics of Solids***
3. ***J. P. Srivastava: Elements of solid state physics (Prentice Hall India; 2nd edition).***
4. ***Christmaan-solid state physics (academic press)***
5. ***A R Verma & O N Srivastava, Crystalolgraphic application to solid state physics***

Core Course-06*: Statistical Mechanics:*

Scope and aim of statistical mechanics: Review of the ideas of phase space, phase points, ensemble and ensemble averages. Statistical equilibrium, condition for statistical equilibrium and Transition from thermodynamics to statistical mechanics. Thermodynamic functions, ideal classical gas, relation to thermodynamic quantities, density of distribution (phase points). Liouville's equation and Liouville's theorem.

Classical Statistic:

A. ***Stationary ensembles:*** Micro canonical, canonical and grand canonical ensembles. Partition function formulation. Fluctuations: Ergodic and quasi-ergodic systems, fluctuations in energy, particle and density; critical opalescence. Equilibrium properties of ideal systems: ideal gas, Harmonic oscillators, rigid rotators, para-magnetism and concept of negative temperature.

B. ***Classical statistics:*** Maxwell-Boltzmann distribution; principal of equipartition; inadequacy of classical theory.

C. ***Density matrix:*** Idea of quantum mechanical ensembles, Statistical and quantum mechanical approaches, properties, pure and mixed states. Equilibrium properties of a system of ideal gases in micro canonical and grand canonical ensembles. Density matrix for stationary ensembles. Application to a free particle in a box, an electron in a magnetic field. Density matrix for a beam of spin ½ particles. Construction of the density matrix for different states (pure and mixture) and calculation of the polarization vector.

D. ***Distribution functions:*** Bose-Einstein and Fermi-Dirac statistics. General equations of state for ideal quantum systems.

Ideal quantum systems:

A. ***Properties of ideal Bose gas:*** Bose-Einstein condensation: Transition in liquid He4, Superfluidity in He4. Photon gas: Planck's radiation law. Phonon gas: Debye's theory of specific heat of solids.

B. ***Properties of ideal Fermi gas:*** Degenerate Fermi gas. Review of the thermal and electrical properties of an ideal electron gas. Landau levels, Landau diamagnetism. White dwarfs and Neutron stars.

C. ***Some applications:*** Specific heats of diatomic gases and crystalline solids; chemical equilibrium; thermal ionization; imperfect gases. Cluster and cluster integrals; The second viral coefficient; van der Wall's equation; cluster expansion of the equation of state of real classical gas.

D. *Irreversible processes:* Onsager's relations; applications.

Strongly interacting systems:

Ising model. Idea of exchange interaction and Heisenberg Hamiltonian. Ising Hamiltonian as a truncated Heisenberg Hamiltonian. Exact solution of one-dimensional Ising system (Matrix methods). Bragg-William's approximation (Mean field theory) and the Bethe-Peierls approximation.

Books Recommended:

1. ***R. K. Pathria, Statistical Mechanics***
2. ***K. Huang, Introduction to Statistical Mechanics***
3. ***Silvio R. A. Salinas, Introduction to Statistical Mechanics.***
4. ***F. Reif, Fundamentals of Statistical and Thermal Physics.***
5. ***Kadanoff, Statistical Mechanics. World Scientific.***
6. ***R. Kubo, Statistical Mechanics. (Collection of problems)***
7. ***Sanchez Bowley, Introductory Statistical Mechanics, Oxford University Press***

Core Course-07: Quantum Mechanics I

General formalism - States, observables and operators in quantum mechanics, Dirac's notation, measurement, co- ordinate and momentum representation. Schrodinger, Heisenberg and interaction picture, Heisenberg's equation of motion.

A. Eigenvalue problems - Matrix method: linear harmonic oscillator, angular momentum, Pauli's spin-1/2 matrices.

B. Approximation methods - Time independent perturbation theory - non-degenerate and degenerate cases, application to one-electron atom. Time dependent perturbation theory, transition probability, Fermi's golden rule, application of time dependent perturbation theory. WKB method, quantization rule, connection formula, application to tunneling through a barrier. Variational method, application to H and He-atom, Ritz principle for excited states.

Symmetries - Symmetries and conservation laws in quantum Mechanics, continuous symmetries, space and time translation, rotation, rotation groups, infinitesimal transformation and Lie groups, Wigner-Eckart theorem, discrete symmetries, parity and time reversal.

Angular momentum - Orbital and spin angular momenta, spin matrices and spinors. Addition of angular momenta, Clebsch-Gordon coefficients.

Many particle system - Identical particles, exchange degeneracy, symmetrization postulate, symmetric wave function and bosons, asymmetric wave function and fermions, Pauli's exclusion principle, BE and FD statistics, second quantization formalism, one and two particle operators in second quantization formalism.

Scattering theory - Partial wave analysis, phase shift, applications, Coulomb scattering, Green's function in scattering theory, Born approximation.

Books Recommended:

1. ***Quantum Physics by Robert Eisberg and Robert Resnick (John Wiley and sons).***
2. ***Quantum Theory by D. Bohm (Prentice-Hall).***
3. ***Quantum Mechanics: Theory and Applications by A. K. Ghatak and S. Lokanathan (Macmillan India Ltd.).***
4. ***Quantum Mechanics by L. I. Schiff (McGraw-Hill Book, New York).***
5. ***Quantum Mechanics by Cohen and Tanaudji.***
6. ***Quantum mechanics by Prabir Ghosh, Narosa Publication***

Core Course-08: Lab course II

(List of experiments should be regarded as suggestive of the standard and may not be strictly adhered to. New experiments of similar standard may be added and old experiments may be deleted whenever felt it necessary).

1. Determination of ultrasonic velocity in liquids using an ultrasonic interferometer.
2. Study of absorption lines of a substance using a spectrograph.
3. To study the spatial and temporal coherence of LASER using Michelson's Interferometer.
4. To study the characteristics curve of G.M. counter, and (a) to study the statistical fluctuation in cosmic ray background radiation, (b) to study the decay of activity of an artificially activated source, (c) to find out the gamma counting efficiency of G.M. tubes, (d) to study the gamma absorption in lead, (e) to study the beta absorption in Aluminum and hence to determine maximum beta energy.
5. To calibrate the given condenser and to determine the values of unknown resistance and capacitance.
6. To find out the dielectric constant of a liquid using a transmission line.
7. To determine the excitation potential of a gas using Frank-Hertz tube.
8. To calibrate a Pirani gauge.

9. Determination of Curie temperature of a ferromagnetic material.

10. To study the optical absorption of a semiconductor and determination of its band gap.

11. Study of Zeeman Effect.

12. Determination of e/m ratio using a magnetron.

13. Study of x-ray diffraction of a simple salt by the powder method and determination of its structure.

14. Measurement of dielectric constant of a polar liquid as a function of temperature and determination of the dipole moment.

Semester-III

Core Course-09: Electrodynamics and Plasma Physics

A. Maxwell's equations, dual field tensor, wave equation for vector ·and scalar potentials and its solution, retarded potential and Lienard-Wiechert potential. Radiation fields, radiated energy and application to linear antenna, Hertz potential and dipole radiation fields, multipole radiation fields. Electric and magnetic fields due to a uniformly moving charge and an accelerated charge, linear and circular acceleration and angular distribution of radiated power, Bremsstrahlung, synchrotron radiation and Cerenkov radiation, reaction force of radiation.

B. Motion' of charged particles in electromagnetic field: Uniform E and B fields, non-uniform fields, diffusion across magnetic fields, time-varying E and B fields. Adiabatic invariants: first, second and third adiabatic invariants.

C. Elementary concepts: Derivation of moment equations from Boltzmann equation, plasma oscillations, Debye shielding, plasma parameters, magneto plasma, plasma confinement.

D. Hydro-dynamical description of plasma: Fundamental equations. Hydro-magnetic waves; magneto-sonic and Alfven waves.

E. Wave phenomena in magneto-plasma: Polarization, phase velocity, group velocity, cutoffs, resonance for electromagnetic wave propagating parallel and perpendicular to the magnetic field, propagation at a finite angle and CMA diagram. Appleton-Hartree formula and propagation through ionosphere and magnetosphere: helicon, Whistler modes and Faraday rotation.

F. Waveguide: Wave guides and resonant cavities: Basic concept of wave guides, TE & TM modes, Rectangular waveguide, circular waveguide, resonant cavities, rectangular cavity resonator-TE, TM modes. Power loss in a cavity. Q factor of a cavity.

Books Recommended:

1. ***Marion- Classical Electrodynamics***
2. ***Jackson- Classical Electrodynamics***
3. ***Panofsky & Phillips- Classical Electrodynamics***
4. ***Chen- Plasma Physics***
5. ***Griffith-Electrodynamics***

Core Course-10: Atomic and Molecular Physics

A. One-electron atom - Quantum states, atomic orbitals; H-atom spectrum, fine structure of H-atom, Lamb-Rutherford experiment, Lamb shift, hyperfine structure.

B. Two-electron atom - Spectral terms, exchange degeneracy, singlet and triplet structure; LS, JJ and mixed coupling schemes.

C. Many-electron atom - Independent particle model, central field approximation, Russel- Saunders coupling, alkali spectra, fine and hyperfine structure in alkali spectra.

D. Interaction with external fields - Time dependent perturbation treatment, electric dipole approximation, stimulated and spontaneous emission, absorption coefficients, selection rules, line broadening, Stark effect.

E. Laser - Emission broadening, Absorption and Gain. Homogeneous broadening, Doppler broadening, Threshold requirements, Population rate equations. Population inversion. Creation of population inversion in 3 level and 4 level lasers. Pumping requirements. Laser cavity modes and coherence length, Fabry Perot resonator, Laser cavity modes and its properties, Q switching, Mode-Locking, Nd: YAG laser.

F. Molecular orbitals - Linear combination of atomic orbital, H -molecular ion, H-molecule, HeitIer London theory.

G. Molecular spectra - Rotation of a diatomic molecule, rotational transition, selection rules, rotational spectra of diatomic molecules as rigid rotor and as non-rigid rotors Stark effect in molecular rotation spectra. Diatomic molecules as linear symmetric top and asymmetric top. Vibration of diatomic molecules, harmonic oscillator, an-harmonicity, selection rules and spectrum, symmetry property of molecular vibration, intensity of spectral lines. Rotation- vibration spectra of diatomic molecules, PQR branching, Raman spectroscopy – pure rotational spectra and vibrational spectra. Electronic spectra of diatomic molecules, Frank- Condon principle. Born-Oppenheimer approximation, vibrational and rotational structure.

Recommended books:

1. Introduction of atomic spectroscopy: White

2. Introduction to molecular spectroscopy: Rajkumar

3. Laser Spectroscopy: Allan Corney

4. Laser in Chemistry- D L Andrew

Core Course-11: Nuclear and Particle Physics I

Nuclear models and basic properties of nuclei - Shell model- experimental evidences - spin-orbit coupling; spin, parity, quadrupole moment, and magnetic moment of nuclear ground states - Schmidt lines; inadequacy / limitations of the shell model.

A. Interaction of radiation with matter - Interaction of heavy particles with matter - specific ionization - Bethe's theory - straggling. Interaction of electrons with matter - range energy relations - Bremsstrahlung: Interaction of gamma radiation with matter - photoelectric effect, Compton scattering and pair production.

B. Nuclear interactions and nuclear reactions - Ground state of deuteron; nucleon-nucleon scattering (low energy) - magnetic moment and quadrupole moment - spin dependence and charge independence of nuclear force. Compound nuclear reaction - reciprocity theorem - Breit-Wigner one-level formula resonance scattering - Ghosal' s experiment.

C. Accelerators and detectors - Cyclotron, synchrocyclotron, synchrotron, betatron - phase stability and phase oscillation. Geiger-Muller counter, bubble chamber, scintillation detector, Cerenkov detector, and semiconductor detector.

D. Nuclear decay - Alpha decay - Gamow's theory - alpha spectrum and systematics. Beta decay -Ferni's theory on beta decay - beta spectrum - selection rules - allowed and forbidden transitions - parity violation - neutrinos. Gamma decay - multipole transition - angular momentum and parity selection rules - internal conversion - nuclear isomerism.

E. Neutron physics and basic theory of nuclear reactors - Passage of neutrons through matter; slowing down, absorption, diffusion and leakage - equation of continuity - Fermi age. Nuclear reactor - condition of criticality - critical size of infinite homogeneous reactors of different shapes.

F. Cosmic rays and elementary particles – Origin of primary cosmic rays - composition and energy spectrum, pions and muons - properties and production - Stroemer's theory - cosmic rays in atmosphere.

G. Different types of interaction of elementary particles classification of elementary particles, isospin and its conservation - SU(2) and SU(3) multiplets - quark model - Gellman-Okubo mass formula; Quantum chromodynamics, quark confinement, asymptotic freedom.

Books Recommended:

2. Nuclear Physics- S. N. Ghoshal (S. Chand Publications)

3. Nuclear Physics- D. C. Tayal (Himalaya Publications)

4. Introductory Nuclear Physics- K. S .Krane (Wiley India)

5. Nuclear Physics: Theory and Experimental- H. S. Hans (New Age International)

6. Nuclear Physics: Theory and Experiment- R. R. Roy and B. P. Nigam (John Wiley and Sons)

GE-1: Laboratory Course III (Programming)

(List of programming problems should be regarded as suggestive of the standard and may not be strictly adhered to. New problems of similar standard may be added and old problems may be deleted whenever felt it necessary)

1. Programming on solution of nonlinear equations by various methods.

a. Root within an interval using Bisection Method.

b. Root within an interval using False position Method.

c. Root near a given point by Newton-Raphson Method.

d. Finding multiple roots through incremental search.

e. Finding multiple roots through deflation and synthetic division.

f. Finding complex roots through Baristows Method

2. Programming on solutions of system of linear equations through

a. Jacobi iteration method

b. Gauss Seidal method and method of relaxation

3. Programming on interpolation methods.

   Finding the Interpolation value at a point, given a set of table points, using

   a. Lagrange interpolation representation
   b. Newton interpolation representation
   c. Natural cubic spline interpolation

4. Curve fitting and regression
   a. Fitting a straight line to a set of data points using method of least squares
   b. Fitting a polynomial curve to a set of data points using method of least squares

5. Problems on numerical differentiations.
   a. Writing programs to evaluate a given function at various points of interest and estimate its first and second derivatives at any specified point

6. Problems on numerical integrations by different methods.
   a. Integrating a given function using Trapezoidal rule
   b. Integrating a given function using Simpson's 1/3 rule
   c. Integrating a given function using Weddle's rule
   d. Integrating a given function using Gaussian quadrature method

7. Programming on numerical solution of ordinary differential equations.
   a. using Euler's method
   b. using Runge-Kutta method

8. Solution of linear systems of equations through matrix methods
   a. Solution of linear systems by determinants
   b. Solution of linear systems through matrix inversion

9. Boundary value and Eigenvalue problem
   a. Determination of coefficients of characteristic polynomial by Fadeev-Leverrier Method.
   b. Determination of Eigenvectors of a system of linear equations .

c. Finding eigenvalue and corresponding eigenvector using power method.

10. Problems on Monte Carlo Technique

    a. Generation of random numbers and

    b. Monte Carlo evaluation of integrals.

Semester-IV

GE-2 (Students have to choose any two courses out of the following courses)

(A) Quantum Mechanics II

Relativistic quantum mechanics - Lorentz group, Klein-Gordon equation, Dirac equation and its plane wave solution, spin and magnetic moment of an electron, negative energy states and its interpretations, covariance of Dirac equation, construction of covariant quantities, large and small components, Pauli's theory as non-relativistic approximation, higher order corrections, central potential, H -atom.

Field quantization - Quantization of a real scalar field and complex scalar field. Quantization of the electromagnetic field, photons, interaction of an atom with radiation field, emission and absorption of radiation. Quantization of Dirac field.

(B) General Relativity

1. Motivation: Anomalous precession of perihelion of mercury from Newtonian viewpoint. Search of relativity for generalized motion of reference frames.

2. Mathematical Preliminaries: Riemannian geometry; vectors and tensors; parallel transport, integrability of parallel transport; covariant differentiation, geodesics; Riemann Christoffel curvature tensor, Bianchi identity; Ricci tensor; curvature scalar; Kretschmann scalar, condition of flatness; Einstein tensor, Weyl tensor, Symmetries and Killing vectors.

3. Gravitational and inertial mass, principle of equivalence (PE) and general covariance; Mach's principle

4. Energy momentum tensor; conservation laws; gravitational red-shift; heuristic derivation of Einstein's field equation;

5. Tests of General Relativity: Perihilion of Mercury, Bending of light, Gravitaitonal lensing, radar echo delay

6. Linearized equations for weak field and gravitational waves.

7. Solutions of Einstein equation in vacuum: Schwarzschild exterior solution; Schwarzschild singularity; integrals of motion; conditions for circular orbits; Innermost Stable Circular Orbit (ISCO), event horizon and black hole; Eddington-Finkelstein coordinates; Kruskal transformation; Kerr metric (without deduction).

8. Mass (ADM) and energy in gravitational field.

Books Recommended:

1. Black holes, white dwarfs and neutron stars, S.L. Shapiro and S. A. Teukolsky, John Wiley, 1983.
2. Gravitation and Cosmology: Principles and applications of the General Theory of Relativity- S. Weinberg, John Wiley, 1972.
3. A First Course in general relativity – B. F. Schutz (CUP)
4. General Relativity : R M Wald
5. Lecture notes on general relativity: S. Carroll
6. Introduction to General Relativity : G. t'Hooft

(C) Laser Physics

1. Introduction: Einstein coefficients, light amplification, threshold condition, line broadening mechanism, Ammonia beam maser, maser operation.

2. ***Coherent states***: Minimum uncertainty wave-function, tirne development of minimum uncertainty wave-function, coherent state of the radiation field, properties of coherent states.

3. ***Semiclassical laser theory***: Electromagnetic field equations, expansion in normal modes of cavity, Lamb's self consistency equations, density matrix equations, polarization of the medium, single mode operation.

4. Gas laser theory: Polarization of Doppler broadened medium, rate equations and solutions, hole burning, two-mode operation.

5. Multimode Operation: Polarization of the media, free-running operation, locking of beat frequencies between N-modes, two-mode operation.

6. Quantum theory of laser: Quantization of the radiation field, photon number states, field equation of motion, laser photon statistics, laser linewidth.

7. Properties of laser beams and types of lasers: Coherence properties of laser light, Spatial and temporal coherence, Directionality, Ruby laser, Helium-Neon laser, Carbon Di-oxide laser, solid state laser, semiconductor diode laser, quantum well lasers, free electron lasers, and dye lasers.

8. Applications of lasers in Science and Industry: (a) Spatial frequency filtering, Holography, three dimensional hologram, reconstruction. (b) Laser induced fusion, laser energy requirements, energy confinement, laser isotope separation. (c) Harmonic generation, Stimulated Raman emission, Self focusing. (d) Lasers in industries: Application in material processing, laser tracking, LIDAR, lasers in medicine.

Books Recommended:

1. ***The quantum Theory of Light – R. Loudon***
2. ***Laser: Theory and Applications – K. Thyagrajan and A.K. Ghatak***
3. ***Laser Physics – M. Sargent III, M.O. Scully and W.E. Lamb Jr.***
4. ***Laser Physics – K. Shimoda***

(D) Physics of Quark & Gluon

Importance of ultra-relativistic heavy-ion collisions, collision scenarios and formation of dense hadronic matter, possibility of the formation of a novel state of matter called quark gluon plasma (QGP), conditions for the formation of QGP, conditions for the application of thermal models and Resume of thermodynamics, state of thermo-chemical equilibrium in nucleus-nucleus reactions, Grand canonical treatment, phase transition theory for hadron to quark transition, application in ideal gas of quarks and gluons within M.I.T Bag model, criteria for a first order quark-hadron phase transition, phase transition at zero temperature, phase transition at finite temperature, phase boundary of quark-hadron phase transition. Evolution of quark-gluon plasma and light quark-antiquark pair and heavy (strange) quark-antiquark production, influence of Pauli blocking of final states, results for static quark gluon plasma, strange particle production in baryon rich plasma. strangeness abundance in hadronic gas in chemical equilibrium, influence of volume (or hydrodynamic) expansion, hadronization scenarios. Signals of quark gluon plasma : strangeness abundances, dilepton and hard photon production, J/Ψ formation.

Books Recommended:

1. Quark Gluon and Hadron Physics, Eds. P.K. Sahu, S.C. Phatak, Y.P. Viyogi, Narosa Publishing House.

2. The Physics of the Quark-Gluon Plasma, Lecture Notes in Physics by Berndt Muller, Springer-Verlag

3. "Quark-Gluon Plasma", Cambridge Monographs on Particle Physics, Nuclear Physics and Cosmology by K. Yagi, T. Hatsuda and Y. Miake, Cambridge University Press.

4. "Finite-Temperature Field Theory Principles and Applications" by Joseph I. Kapusta and Charles Gale, Cambridge Monographs on Mathematical Physics, Cambridge University Press.

5. "Quarks and Gluons at High Temperatures and Densities" by J. Cleymans, R.V. Gavai and E. Suhonen, Physics Reports, Vol. 130, No. 4, pp 217 – 292.

6. "Strangeness in Relativistic Heavy Ion Collisions", by P. Koch, B. Muller and J. Rafelski, Physics Reports, Vol. 142, No. 4, pp 167 – 262.

DCE-1: **(Students have to choose any one course)**

Group – A: Condensed Matter Physics II

Lattice dynamics: Born-Oppenheimer approximation; phonons; photon-phonon, electron- phonon and neutron-phonon interactions; N-process and U-process; phonon spectrum; singularities in phonon spectrum; Van Hove's theorem (statement only); Debye-Waller factor; an-harmonic effects; thermal expansion and thermal conductivity for determining phonon dispersion curves.

Ferromagnetism: Exchange interaction and Heisenberg's theory of ferromagnetism; Block's theory of free electron ferromagnetism; collective electron theory; magnons; magnon

dispersion relation (for both ferro and anti-ferromagnetie substances); Block's T 3/2 law; neutron scattering by magnons; Ising model; Landau's theory of diamagnetism.

Magnetic resonance: Basic theory; spin-spin and spin -lattice relaxation processes; Bloch equations; steady state solutions; Bloch susceptibilities; line width; motional narrowing; nuclear magnetic resonance (NMR); Knight shift in metals; electron spin resonance (ESR); crystal field theory; ENDOR; Overhauser effect; methods for measuring relaxation times; SWR, RME, AFFMR, Mossbauer effect; Mossbauer's experiment, Mossbauer coefficient - classical and quantum theory, red shift, isomer shift, quadrupole coupling, magnetic hyperfine structure.

Superconductivity; Heat capacity and infra-red properties of superconductors; London equation; penetration depth; coherence length; Cooper theory; Cooper pairs; BCS theory; quasi particles; flux quantization; Grover tunneling; Josephson tunneling; AC and DC effects; SQUID.

Critical Phenomena: Order parameter; Landau theory; first & second order phase transitions; critical indices; scale invariance hypothesis; effective Hamiltonian; fluctuations of order parameter, examples of systems sharing critical behavior.

Group – B: Nuclear and Particle Physics II

A. Two-nucleon system - Deuteron problem - ground state of deuteron with non-central force, quadrupole moment and magnetic moment. Scattering length, effective range theory for n-p and p-p scattering at low energy - saturation of density and binding energy, exchange force.

B. Nuclear models - Evidence of collective model, phenomenological collective model, rotational and vibrational states, coupling of single particle with collective motion, single particle in deformed potential- Nilsson model.

C. Nuclear interactions at high energy - Nucleon-nucleon interaction at high energy and hadron structure, nucleon-nucleon potentials, meson theory, Yukawa interaction, polarization in nucleon-nnucleon scattering, scattering matrix. Probing charge distribution with electrons, form factors, deep inelastic e-p scattering.

D. Nuclear reactions - Theory of elastic and inelastic scattering, coupled channels - distorted wave Born approximation - optical model, limitations of optical model. Statistical theory of compound nucleus, resonances; theory of direct reaction.

E. Accelerators and detectors - Principle of phase stability and phase oscillation in case of synchrocyclotron and synchrotron. Betatron oscillations. Linear accelerators, Pelletrons and microtrons. Focusing of particle beam, sector focused cyclotron, alternating gradient focusing.

F. Detectors Proportional counters, multiwire proportional counters, Drift chamber, Streamer chamber, Calorimeters.

G. Relativistic Heavy-ion Interaction: MIT Bag model of a nucleus; Quark-gluon Plasma (QGP); QGP at high-temperature; QGP at high baryon density. Hydrodynamics of QGO; Bjorken's estimation of energy density in high-energy nucleus-nucleus interaction. Signatures of QGP – qualitative discussion.

Group – C: Electronics II

Vacuum tube ultra-high frequency and microwave oscillators:

Difficulties of using ordinary vacuum tubes in UHF range. Theory of operation of magnetron, klystron, travelling-wave tube and backward-wave oscillators.

Semiconductor microwave devices:

Structure and principle of operation of tunnel diode/ negative resistance oscillator; varactert diode, parametric amplifier; IMPATT diode, QWITT diode. Gunn Effect: two-valley model for bulk microwave generation; MESFET.

Semiconductor optoelectronic devices:

LED, APD (avalanche photodiode, p-i-n diode, semiconductor lasers, charge-couple-devices (CCD), optocoupler; Drive circuit for LED and lasers.

Transmission lines:

Voltage and current relations; attenuation constant and phase constant; characteristic impedance; reflection coefficient; standing-wave ratio; open and short-circuited lines and lines terminated with finite impedance; behaviour of lines of different lengths; Q of a transmission line; Transmission line measurements. Smith chart.

Wave guide and cavity resonator:

Theory of wave propagation between conducting parallel planes and in rectangular and cylindrical waveguides; Modes of electromagnetic radiation in a cavity: TE and TM modes, cut-off frequency, group and phase velocities; waveguide measurements. Rectangular and cylindrical cavity resonators; Q of a resonator; Horn antennas.

Antennas:

Directive gain; Radiated power and radiation resistance; Dipole antenna; Vertical antenna of different lengths; Arrays of antennas Loop, Yagi and other special purpose antennas.

Radio wave propagation

Space wave propagation; atmospheric effects; the ionosphere and its layers; effect of magnetic field of the earth; reflection and refraction of sky waves by the ionosphere; skip distance and maximum usable frequency; fading; Chapman's theory of formation of ionospheric layers; measurement of ionospheric height and electron concentration; Solar activity and its effect on radio wave propagation.

Group – D: Astrophysics

Astronomical units and parameters: Luminosity, stellar magnitudes, distance modulus relation, parallax methods.
Celestial coordinates: Naming convention of astronomical objects, catalogues Astronomical observation: different spectrum bands, H-R diagram: classification of stellar objects from HR diagram.
Star formation: Pre-main sequence star, main sequence star, Virial theorem. Thermal paradox, Kelvin Helmholtz time scale, Radiative transfer equation.
Basic equation of stellar structure: Newtonian Stars, Hydrostatic equilibrium, Homologous stellar models, mass-luminosity relation, Relation to HR diagram. Polytropic equation of state, Lane-Emden equation and its analytic solutions.
Sun - general features.
Thermonuclear reactions in stars: pp chain, CNO cycle; solar neutrino problem, subsequent thermonuclear reactions, helium burning, nucleosynthesis beyond iron.

Stellar evolution: white dwarf, Electron degeneracy pressure, Chandrasekhar mass limit,
Static spherically symmetric spacetime: Physical interpretation of metric potentials. Gravitational

redshift.
Perfect Fluid: Equation of state, equation of motion, TOV equation, stars of uniform density, limit of mass to radius ratio. Newtonian Limit.
Neutron Stars: Schematic Structure and general features. TOV equation applied to neutron stars, Neutron degeneracy pressure, Maximum mass of neutron stars. Pulsars.
Binary stars: Roche Lobe and Lagrange points; accretion process.
Black Holes: Creation of black holes, Schwarzschild black hole, Event Horizon and its nature, infinite redshift, Light cone, Removal of coordinate singularity, Eddington- Finkelstein and Kruskal-Szekres coordinates, Penrose diagram. No hair theorem (statement only) Hawking Area Theorem (statement only), surface gravity, four laws of BH thermodynamics, Penrose process, Hawking Radiation (qualitative discussion), BH evaporation.
Active galactic nuclei, Supermassive black holes, Quasi-stellar Objects (Quasars), Blazars.

Books Recommended:

1. *Black holes, white dwarfs and neutron stars*, S. L. Shapiro and S. A. Teukolsky, John Wiley, 1983.
2. *An introduction to the study of stellar structure*, S. Chandrasekhar, Dover.
3. R*elativistic astrophysics,* Ya B. Zel'dovich and I.D. Novikov, Vol.-I, University of Chicago press.
4. The*oretical astrophysics, Vol.-I, II and III*, T. Padmanabhan, CUP.
5. *Gravitation and Cosmology: Principles and applications of the General Theory of Relativity*- S. Weinberg, John Wiley, 1972.
6. *Gravity:* Hartle (Pearson Education)
7. *A First Course in general relativity* – B. F. Schutz (CUP)
8. *General Relativity* : R M Wald
9. *Lecture notes on general relativity:* S. Carroll
10. *Introduction to General Relativity* : G. t'Hooft
11. *Introduction to Modern Astrophysics:* Bradly W. Carroll and Dale A. Ostlie, (Pearson)
12. Astrophysics: Arnab Raychaudhuri

DCE-2: (Students have to choose any one course)

Group – A: Condensed Matter Physics III

Structure determination of solids: Crystal symmetry, Bravais lattice; transformation of crystal lattices; point groups; space groups; simple application of group theory to symmetry of crystals; space group determination; rotation and Weissenberg photographs; Fourier transform and its application; theory of structure analysis; Patterson synthesis and its application in structure determination; direct methods of crystal structure determination; diffraction of X- rays in presence of thermal vibrations; electron diffraction and neutron diffraction for structure determination. Advantage of neutron diffraction over X-ray diffraction, general idea of defects in crystals, color centers; quasi crystals, Nanomaterials; liquid crystals; Elementary concepts of surface crystallography, scanning, tunneling & atomic force microscopy.

Band theory of solids: Calculation of energy bands in solids; tight binding and LCAO methods; OPW method; cellular and augmented plane wave method; symmetry of energy bands; calculated energy bands; experimental study of electronic energy levels in solids; cyclotron resonance; anomalous skin effects; de Haas-van Alphen effect.

Semiconductors: Band structure of common semiconductors; effective mass theory; intrinsic and extrinsic semiconductor - statistics of electron-hole carriers and Fermi energy; dynamics of electrons ands holes; generation and recombination processes; surface recombination; Shockley-Reed mechanism of recombination; life time of carriers; Hall effect and Hall coefficient for two carrier types, origin of positive Hall coefficient for metals, modification of Hall coefficient for velocity distribution of carriers.

Dielectric properties: Dielectric polarization; Debye's theory of dielectric relaxation, Cole- Cole plot, Onsager-Kirkwood theory, Ferroelectricity; ferroelectric crystals Barium Titannate etc. ; polarization catastrophe; LST relation in ferroelectrics.

Optical properties: Drude-Lorenz theory of metals and insulators; complex dielectric constant and its relation with optical properties of a solid; dispersion and absorption; reflection and absorption coefficients; Kramers-Kronig relations; quantum theory of optical transitions in a solid; direct and indirect, allowed and forbidden transitions; excitons; Frenkel and Mott- Wannier excitons.

Group – B: Nuclear and Particle Physics III

Relativistic kinematics - Laboratory system and C.M. system, Lorentz transformation; Mandelstam variables, invariant cross-section, phase space density.

Symmetries - Lie groups, Lie algebra, root and weight diagrams, Young's tableau, SU(2) and SU(3) groups. Discrete symmetries, parity, charge conjugation, and time reversal - CPT theorem. Noether’s theorem and conserved currents. Gauge theories, abelian and non-abelian gauge invariance, spontaneous symmetry breaking and Higg's mechanism.

Quantum electrodynamics – Elements of Dirac's theory. Free field theory; scalar, spinor and vectors fields; covariant commutation relations and Feynman's propagators. Interacting field theory; covariant perturbation theory, S-matrix, Wick's theorem, cross-section and decay rates; spin sum and averaging; Feynman rules and graphs for QED. Lepton-lepton scattering; Moller scattering, Bhabha scattering, Compton scattering; electron – nucleus scattering.

Group – C: Electronics III

Communication principles:

Amplitude, frequency and phase modulation; Methods of modulation and demodulation; Double-sideband (DSB) suppressed carrier, single sideband (SSB) and vestigial sideband modulation; various techniques of pulse modulation and detection, PAM, PCM. Application to T V and Radar- Basic principles of TV transmission and reception; Elements of radar, azimuth and range measurements.

Microwave communications:

Advantages and disadvantages of microwave transmission; propagation of microwaves, loss in free space; atmospheric effects and propagation; Fresnel zone problem, ground reflection, fading sources.

Microwave communication system - Multiplexing, repeaters, detectors, components and antennas.

Satellite communication:
Kepler's law and orbital satellites, geostationary satellites, station keeping; orbital patterns, look angles, orbital spacing, various satellite systems, link modules; Transmission path; Power budget calculations.

Fibre optic communication:

Optical fibre- An optical waveguide, total internal reflection, numerical aperture; Advantages; Manufacture of fibres and cables, splices; various kinds of losses; Dispersion.

Optical communication systems- Transmitter, receiver; Point-to-point fibre link; wavelength division multiplexing (WDM); Repeater and optical amplifier.

Advanced Digital Circuits:
Shift registers; asynchronous and synchronous counters, Cascade counters; (ROM), PROM and PLA, EPROM; Random-access memory (RAM) and their applications. Digital to analog and

analog-converters.

Digital Communication:
Advantages and disadvantages: Sampling theorem, quantization Sample and hold (S/H) circuit. Pulse code modulation (PCM), delta modulation, adaptive delta modulation; ASK, FSK, PSK, DPSK, coherent and non-coherent ASK,PSK and FSK signals; Data communication.

Microprocessor:
Introduction to microprocessor: Neumann's architecture, BUS structure. Intel 8085 CPU – architecture with functional blocks and ALU; Register sections.
Assembly language programming – Instruction format with simple examples, looping and time delay.

Group – D: Cosmology

Introduction to Cosmology: Cosmological Principle, observational basis for cosmological theories, Hubble's law, big bang cosmology.
Homogeneous Isotropic world models: Derivation of Friedmann models and their properties, radiation dominated and matter dominated universe, the distance scale, the age of the universe, the density parameter.
Physics of the Big Bang: Thermal history of the universe, cosmological nucleosynthesis, the cosmic microwave background radiation (CMBR), the decoupling era, large- and small- scale anisotropy in the CMBR. Problems of the Standard Model and its remedies.
Galaxy: Milky Way as a galaxy, Classification and morphology of galaxies, dynamics of galaxies, rotation curves and dark matter, galaxy properties, scaling relations.
Large scale structure of the Universe: Redshift surveys of galaxies, measures of the galaxy distribution, correlation functions and power spectra, topological measures of galaxy distribution.
Reionization of the Universe: The first stars, the reionization process.

Books Recommended:

1. Introduction to Cosmology: J. V. Narlikar, CUP
2. Modern Cosmology: S. Dodelson, Academic Press
3. Gravitation: C. W. Misner, K. S. Thorne and J. A. Wheeler, W. H. Freeman and Co.
4. Cosmology and Astrophysics through problems: T. Padmanabhan, CUP

DCE-3: (Students have to choose any one course)

Lab Course IV
(List of experiments should be regarded as suggestive of the standard and may not be strictly adhered to. New experiments of similar standard may be added and old experiments may be deleted whenever felt it necessary).

Group – A: Condensed Matter Physics

1. Measurement of the Hall coefficient of a given sample and calculation of its carrier concentration.
2. Measurement of the energy gaps of (i) silicon and (ii) germanium.
3. Measurement of the coercive field and saturation polarization of a ferroelectric sample.
4. Measurement of the anisotropy of magnetic susceptibility of crystal by (i) Krishnan's method and (ii) Oscillation method.
5. Determination of spin-spin relaxation time of a given sample and the value of the spectroscopic splitting factor (g) by ESR method.
6. Determination of the concentration of color centers in an alkali halides crystal.
7. Study of the characteristics of a photo-diode and calculation of its efficiency of energy conversion.
8. Determination of the value of the lattice parameter and Bravais lattice type of a cubic crystal by Debye-Scherrer method.
9. Obtaining the Laue photograph of a single crystal and drawing gnomonic projections and indexing the spots.
10. Determination of the transverse magneto-resistance coefficient of a given sample and finding the mobility of the carriers.
11. Determination of the cell dimensions of a given single crystal from rotation photograph.

Group – B: Nuclear and Particle Physics

1. To study the gamma ray spectra using a scintillator detector and a single channel analyzer.
2. To calibrate the gamma ray spectrometer, and to find out its resolution and efficiency for gamma detection.
3. Measurement of Compton scattering cross-section and photoelectric effect cross-section.
4. To study gamma absorption in Pb/Hg using gamma ray spectrometer.
5. To study the beta absorption in AI, using G.M. counter - Feather's method.

6. To study Rutherford's scattering of alpha particles.
7. To study the beta spectrum from different beta sources.
8. To study the Compton Effect using scintillator.
9. To study (i) the hadronic interactions, (ii) heavy-ion interactions, (iii) pi-mu decay, and (iv) to measure charge of nuclear fragments in nuclear emulsion.

Group – C: Electronics III

(List of experiments should be regarded as suggestive of the standard and may not be strictly adhered to. New experiments of similar standard may be added and old experiments may be deleted whenever felt it necessary).

1. Design and construct Butterworth First order, second order and 4^{th} order Low pass, High pass filters. Plot the frequency response curves for these low pass filters. Determine the phase angles and the cut off frequencies.
2. Using an IC-555 construct the following circuits and study them:
 (a) Astable Multivibrator (b) Schmitt Trigger (c) Sawtooth wave generator (d) Voltage Controlled Oscillator generator.
3. Design and study the following properties of a positive voltage power supply using an IC 723.
   (i) Variation of output voltage with input voltage.
   (ii) Effect of load current on stabilized output voltage for two different line voltages.
   (iii) Same as (ii) when a series pass transistor 2N3055 is connected as a current booster.
   (iv) Determine the voltage stabilization ratio S_v, output resistance Ro.
4. (a). Design and study an amplitude modulator circuit using transistor and determine the percentage of modulation by (i) envelope method, (ii) trapezium method.
   (b). To construct a detector circuit for AM waves and study its performance.
5. To detect frequency modulated waves using the IC phase-locked loop
6. (a) To construct and study a four bit ripple counter.
   (a) To construct and study a decade counting unit.
7. **Experiments on Fiber Optics**:

i. Setting up Fiber Optics analog link
ii. Setting up Fiber Optics digital link
iii. Intensity modulation system using analog input
iv. Intensity modulation system using digital input
v. Frequency modulation system

vi. Pulse modulation system

vii. Propagation loss in optical fiber

viii. Ben ding loss in optical fiber

ix. Measurement of optical power using optical power meter(OPM)

x. Measurement of propagation loss using OPM

xi. Measurement of Numerical Aperture

xii. Setting up of FO voice link using Intensity Modulation

xiii. Setting up of FO voice link using FM

xiv. Setting up of FO voice link using PWM

8. **Experiments with the 8085 microprocessor**: **Microwave Experiments:**

(a) To study the characteristics of wave propagation in a waveguide by studying standing wave pattern and hence to plot ω-β diagram.

(b) To verify relationship between guide wavelength λ and free space wavelength using a wave-guide slotted section

(c) To study the mode characteristics reflex Klystron and hence to determine mode number, transit time, electronic tuning range (ETR) and electronic tuning sensitivity (ETS).

(d) To study Gunn oscillator as a source of microwave power and hence to study (a) I-V characteristics, (b) Power frequency versus bias characteristics and (c) power-frequency characteristics.

(e) To study the properties of E-and H-plane waveguide tee junctions and to determine isolations, coupling coefficients and input VSWRs.

(f) To study isolation. Coupling coefficients and input VSWRs of an E-H tee or Magic tee.

(g) To study E-plane and H-plane radiation pattern of a pyramidal horn antenna and compute (a) beam width and (b) Directional gain of the antenna.

(h) To study the characteristics of a directional coupler.

(i) To study the operation of a ferrite circulator and hence measure (a) insertion loss, (b) isolation (c) Cross coupling (d) Input VSWR at a given frequency and study their variation with frequency.

Group – D: Computer application in General Relativity, Astrophysics and Cosmology

1. Introduction to Mathematica, LaTeX, Data analysis.

Part-I: Computer application

Mathematica:

Concepts of CAS, Basics operations in Mathematica, elementary calculations, Algebra, Calculus, Numerical Analysis, Graphics and plots, Functions,
Writing elementary programs, Do-While loop.

Latex:

Fundamentals, Creating a document, article, book, Writing equations. Formatting tables. \usepackage commands, Inserting figures, Writing long documents, \input, \include commands, defining macros, \def, \newcommand, \renewcommand, Composing presentations.

Data Analysis:

1. Find the light curve of a given target using HEASOFT software in SUZAKU/NuSTAR instrument.
2. Find the SPIN motion of a given target using HEASOFT software in SUZAKU/NuSTAR instrument.

New experiments will be introduced by concerned faculty members.

2. Project: Students will have to submit and presnt one project work.