Post Graduate Syllabus
Department of Physics
University of North Bengal

Choice-based Credit System

Introduced from the Academic Session 2017-18

Semester I	Semester II
Paper I – Mathematical Methods in Physics: 50+25 (2+1) Paper II – Classical Mechanics: 50+25 (2+1) Paper III – Electronics I: 50+25 (2+1) Paper IV – Computational Methods in Physics I: 50+25 (2+1) Paper V – Laboratory Course I: 100 (4)	Paper VI – Electrodynamics & Plasma Physics: 50+25 (2+1) Paper VII – Statistical Mechanics: 50+25 (2+1) Paper VIII – Quantum Mechanics I: 50+25 (2+1) Paper IX – Computational Methods in Physics II: 75 (3) Paper X – Comprehensive Course I: 75 (3) Paper XI – Comprehensive Viva-voce I: 25 (1)
Semester III	**Semester IV**
Paper XII – Quantum Mechanics II: 50+25 (2+1) Paper XIII – Condensed Matter Physics I: 50+25 (2+1) Paper XIV – Nuclear & Particle Physics I: 50+25 (2+1) Paper XV – Atomic & Molecular Physics: 50+25 (2+1) Paper XVI – Laboratory Course II: 100 (4)	Paper XVII –Astrophysics & Cosmology: 50+25 (2+1) Paper XVIII – Elective Paper I: 50+25 (2+1) Paper XIX – Elective Paper II: 50+25 (2+1) Paper XX – Laboratory Course III: 75 (3) Paper XXI – Comprehensive Couse II : 75 (3) Paper XXII - Comprehensive Viva-voce II : 25 (1)

v *Salient features of the PG syllabus:*

1. *Total marks allotted to all papers in M.Sc. in Physics Examination will be **1600** (equivalently **64** credits), distributed equally in four semesters (**400** $\times$ **4**) or (16 credits $\times$ 4). Full marks and equivalent credit (shown within parentheses) have been mentioned above against each paper, and explained below in details.*

2. *Elective papers to be offered at present will be: (i) Condensed Matter Physics, (ii) Nuclear and Particle Physics, and (iii) Electronics – only in Semester IV.*

3. *There will be a theoretical examination against Paper – IV (Computational Methods in Physics I) and a practical examination against Paper – IX (Computational Methods in Physics II).*

4. *In each theory paper the end semester examination (ESE) of Semester I, II, III & IV will be conducted over a total marks of **50** (2 credits) of two and half hours duration, while continuous evaluation (CE) will be made over **25** marks (1 credit). For Laboratory Course I, II & III, ESE will be conducted over 100 marks (4 credits). Computational Methods in Physics II, the ESE will be conducted over **75** marks (3 credits). Only ESE will be conducted in Papers X & XXI, over 75 marks (3 credits) for each, covering the contents of Paper I, II, III, VI, VII & VIII for Paper X, and the contents of Paper XII, XIII, XIV, XV & XVII for paper XXII. In these two papers questions will ordinarily be like the National and State Level Eligibility Tests for recruiting research scholars. In each theory paper the CE may comprise of Class Tests and/or Home Assignments.*

5. *The marks / grade obtained by a candidate in each paper/course should be determined after taking into account the marks / grade obtained by the candidate in ESE and CE together.*

6. *The Comprehensive Viva-voce I will be based on the knowledge acquired in papers I, II, III, VI, VII & VIII taught in Semesters I and II. Similarly, Comprehensive Viva-voce II will be based on the knowledge acquired in papers XII, XIII, XIV, XV and XVII taught in semesters III and IV.*

Semester I						
Paper	Code	Course	ESE		CE	
			Marks	Credit	Marks	Credit
I	PHY 1101	Mathematical Methods in Physics	50	2	25	1
II	PHY 1102	Classical Mechanics	50	2	25	1
III	PHY 1103	Electronics I	50	2	25	1
IV	PHY 1104	Computational Methods in Physics I	50	2	25	1
V	PHY 1305	Laboratory Course I	100	4		

Semester II						
Paper	Code	Course	ESE		CE	
			Marks	Credit	Marks	Credit
V I	PHY 2106	Electrodynamics & Plasma Physics	50	2	25	1
VII	PHY 2107	Statistical Mechanics	50	2	25	1
VIII	PHY 2108	Quantum Mechanics I	50	2	25	1
IX	PHY 2309	Computational Methods in Physics II	75	3	-	-
X	PHY 2110	Comprehensive Course I	75	3	-	-
XI	PHY 2111	Comprehensive Viva-voce I			25	1

Semester III						
Paper	Code	Course	ESE		CE	
			Marks	Credit	Marks	Credit
XII	PHY 3112	Quantum Mechanics II	50	2	25	1
XIII	PHY 3113	Condensed Matter Physics I	50	2	25	1
XIV	PHY 3114	Nuclear & Particle Physics I	50	2	25	1
XV	PHY 3115	Atomic & Molecular Physics	50	2	25	1
XVI	PHY 3316	Laboratory Course II	100	4		

Semester IV						
Paper	Code	Course	ESE		CE	
			Marks	Credit	Marks	Credit
XVII	PHY 4117	Astrophysics & Cosmology	50	2	25	1
XVIII	PHY 4118/4119/4120	Elective- I	50	2	25	1
XIX	PHY 4121/4122/4123	Elective- II	50	2	25	1
XX	PHY 4324	Laboratory Course III	75	3	-	-

XXI	PHY 4125	Comprehensive Course II	75	3	-	-
XXII	PHY 4226	Comprehensive Viva-voce II	-	-	25	1

Semester I

Paper – I: Mathematical Methods in Physics

A. Complex analysis: Functions of complex variables, regular and singular points. Cauchy – Riemann equations. Cauchy's theorem and consequences, integral formulae. Expansion of functions about regular and singular points. Residue theorem – its application in evaluating integrals and series summations.

B. Partial differential equations and integral transforms: Separation of variables for second order partial differential equations. Integral transforms - Fourier and Laplace transforms.

C. Differential equations and special functions: Series solution of linear second order differential equations; Legendre, Bessel, Hermite and confluent hypergeometric equations. Dirac's delta function; Gamma and Beta functions; Legendre and associated Legendre polynomials – spherical harmonics; Hermite and Laguerre polynomials.

D. Linear vector space and matrices: Definition of vector space, dimension, basis, subspace, inner product, orthogonality and completeness. Linear operators – matrix representation of operators. Change of basis. Matrices – eigenvalue problem, diagonalization of matrices, series of matrices.

E. Tensors: Covariant, contravariant and mixed tensors. Tensor algebra, contraction, quotient law. Kronecker delta, Levi-civita symbol and metric tensors. Christoffel symbols and covariant derivative of tensors.

F. Group theory: Introduction, group multiplication table, discrete and continuous groups. Reducible and irreducible representation of groups, equivalent representation. Schur's lemma, orthogonality theorem. rotation groups, unitary groups, Lorentz homogeneous groups.

G. Green's function: Nonhomogeneous boundary value problem and Green's function, eigenfunction expansion of Green's function, Fourier transformation method of constructing Green's function, application to physical problems.

Books:

Mathematical methods for physicists – G. B. Arfken & H. J. Weber
Mathematical methods in classical and quantum physics - Tulsi Dass & S. K. Sharma
Mathematical Physics – H. K. Dass
Mathematical Physics – P. K. Chattopadhyay
Complex variables – M. R. Spiegel
Linear Algebra – S. Lipschutz
Matrices and Tensors – A. W. Joshi

Paper – II: Classical Mechanics

A. Lagrange's and Hamilton's formalisms: Generalized coordinates, Virtual work and D' Alembert's principle. Principle of least action, Lagrange's equation of motion – applications. Hamilton's principle – applications. Noether's theorem, symmetry and conservation rules.

B. Two-body central force problem: Central force, definition and characteristics; effective potential technique; study of Keplarian systems, graphical analysis.

C. Rigid body kinematics: Kinematics of rigid body motion; degrees of freedom; Euler angles; The Cayley-Klein parameters and spinors; rigid rotator & heavy symmetrical top.

D. Hamilton's equations: Legendre transformation, Hamilton's canonical equations and Routh's procedure.

E. 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.

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

G. Small oscillations: Stable and unstable equilibria; small oscillations; vibration and normal co-ordinates.

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

I. Non-linear dynamics: Periodic motions and perturbations; Attractors; Chaotic trajectories and Liapunov exponents.

J. Special theory of relativity: Minkowski space, four vectors and metric; Lagrangian formulation of relativistic mechanics; covariant formulation of Maxwell's equations.

Books:

Mechanics (Course of Theoretical Physics, Vol. I) – L. Landau & E. Lifshitz

Classical Mechanics – H. Goldstein, C. Poole & J. Safko
Classical Mechanics, Vol. II – E. A. Desloge
Classical Mechanics – N. C. Rana & P. S. Joag
Nonlinear Dynamics & Chaos – S. H. Strogatz
Chaotic Dynamics - An Introduction – G. L. Baker & J. P. Gollub
Classical Mechanics – S. N. Biswas
Special theory of relativity – Banerjee & Banerjee

Paper – III: Electronics I

A. Physics of Semiconductor devices: Metal semiconductor junctions – Schottky barriers; Rectifying contacts; Ohmic contacts; Typical Schottky barriers. Misc. semiconductor devices – Tunnel diode; Photodiode; Gunn diode; IMPATT diode; Solar cell; LED; LDR; p-n-p-n switch, SCR; Unijunction transistor (UJT).

B. 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.

C. Audio power amplifiers: Audio power amplifier requirements, Class A, Class B and Class C power amplifiers, Push pull and tuned power amplifiers.

D. Oscillators: Feedback sinusoidal oscillator and condition of oscillation, Phase-shift oscillator, Wien bridge oscillator and Multivibrator using BJTIFET; Negative resistance oscillator.

E. Power supplies and Electronic regulators: Linear Power supply, Electronic voltage regulators, variable voltage supplies using SCR, IC etc. Switch Mode Power supply, Uninterrupted Power Supply, Step up and Step down Switching Voltage Regulators.

F. VLSI fabrication technology: Process steps for IC Technology- cleaning, oxidation, diffusion, ion implantation, lithography, etching metallization, Fabrication of monolithic IC, VLSI design- design rules, stick diagram, chip assembly and packaging techniques. CMOS fabrications.

G. OP AMP: Differential amplifiers, DC and AC analysis, CMRR, constant current bias level translator. Block diagram of a typical OP-AMP circuit: Open-loop configuration. Inverting and non-inverting amplifiers. OP AMP with negative feedback - voltage series feedback. Effect of feedback on closed loop gain, input resistance, output resistance, bandwidth, offset voltage and current, voltage follower.

H. 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.

I. Special circuits using OP AMP: Comparators, square wave and triangle wave generators, voltage regulators, fixed and adjustable voltage regulators, switching regulators, active filters.

J. Digital Electronics: Digital Circuits: Logic functions; Logic simplification using Karnaugh maps; SOP and POS design of logic circuits; MUX as universal building block. RCA, CLA and BCD adder circuits; ADD-SHIFT and array multiplier circuits. RS, JK and MS-JK flip-flops; registers and counters.

K. 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:

Electronics fundamentals and application: John D. Ryder
Hand book of Electronics: Gupta and Kumar
Electronic Principles: Malvino
Principles of Electronics: Mehta and Mehta
Networks lines and fields: John D. Ryder
Solid state electronic devices: G . Streetman
Physics of semiconductor Devices: S. M. Sze
Electronic circuits and systems: Y. N. Bapat
Integrated Electronics: Millman and Halkias
Electronics fundamentals and application: Chattopadyay and Rakshit
Electronics (Classical and modern): R. Kar
Fundamentals of digital circuit: Anand Kumar
Lab. Experiments and PSPICE Simulations in Analog electronics: L. K. Maheswary and M.M.S. Anand

Paper – IV: Computational Methods in Physics I

A. Introduction: Fundamentals of a computer and its working principle; different number systems; representation of integer and real numbers; ASCII codes.

B. Programming: Instructions to a computer; machine language; high level language; different programming languages; Interpreter and compiler; overview of FORTRAN language; input-output statements; mathematical assignment statements; control statements; function and subroutine sub-programmes; subscripted variables; string variables; operations with complex numbers, data files, reading writing and appending data files

C. 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.

D. Interpolation: Newton's formulae; 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.

E. 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; Bairstow's method for complex roots.

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

G. Eigenvalues and eigenvectors of matrices: Power and Jacobi method

H. Solution of differential equations: Euler's and Picard's methods; Milne's method; Runge-Kutta method; Multistep method; solution of 2nd order differential equations.

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

J. Random numbers: Properties of random numbers; generation of random numbers; Monte Carlo evaluation of integrals.

Books:

Fundamentals of Computers V. Rajaraman
Computer programming in Fortran IV V. Rajaraman
Computer oriented numerical methods V. Rajaraman
Fortran 77: A structured, disciplined style: G B Davis and T R Hoffmann
Numerical methoda for mathematics, science and engineering: J H Mathews
Numerical recipies in fortran: W H Press, S A Teukolski, W T Vetterling and B P Flannery

Paper – V: 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)

1. 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.

2. 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.

3. To study OPAMP as voltage regulator and show the variation of load voltage with load current.

4. Studies on Diac, Triac and SCR.

5. 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.

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

7. To design an astable multi vibrator 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 a Schmitt trigger or Zener diode.

8. 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.

9. To study the various feedback amplifier using OPAMP

   i. Voltage series feedback amplifier (VCVS)

   ii. Voltage shunt feedback amplifier (CCVS)

   iii. Current series feedback amplifier (VCCS)

   iv. Current shunt feedback amplifier (CCCS)

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

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

12. To study the various type of digital- to- analog (D/A) converters.

13. 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).

Semester II

Paper – VI: Electrodynamics and Plasma Physics

A. Classical Electrodynamics: 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, nonuniform fields, diffusion across magnetic fields, time-varying **E** and **B** fields. Adiabatic invariants – first, second and third adiabatic invariants.

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

D. Hydrodynamical description of plasma: Fundamental equations. Hydromagnetic waves; magnetosonic and Alfven waves.

E. Wave phenomena in magnetoplasma: Polarisation, 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.

Books:

Classical electricity & magnetism – Panofsky & Philips
Introduction to electrodynamics – D. H. Griffiths
Classical Electrodynamivs – J. D. Jackson

Plasma physics & controlled fusion – F. Chen
Plasma mechanics – B. Chakrabarty
Plasma physics – Tanenbaugh
Plasma physics – S. N. Sen
Plasma physics – G. Francis

Paper – VII: Statistical Mechanics

A. Classical Statistical Mechanics: Postulate of classical statistical mechanics, Microcanonical ensemble, statistical mechanics and thermodynamics, classical ideal gas, Gibbs paradox, canonical and grand canonical ensembles, conditions for statistical equilibrium, thermodynamic functions, partition function and grand partition function, relation to thermodynamic quantities phase space, density function, Liouville's theorem, equipartition theorem, fluctuations, ergodic & quasi-ergodic systems, equivalence of different ensembles. Maxwell-Boltzmann distribution, applications, inadequacy of classical theory.

B. Density matrix and its properties: Postulates of quantum statistical mechanics, identical particles and many particle states, density matrix, ensembles in quantum statistics, equilibrium properties of an ideal gas in different ensembles.

C. Bose-Einstein statistics: Application to photons, Planck's formula; phonons in solids, Bose-Einstein condensation; liquid Helium II.

D. Fermi-Dirac statistics: Thermodynamics of an ideal Fermi gas, degenerate Fermi gas, white dwarf stars, specific heat of crystalline solids, thermal ionization – Saha's formula, Pauli's theory of paramagnetism.

E. Elements of lattice statistics: Ising model.

Books:

Statistical Mechanics – R. K. Pathria
Statistical Mechanics – K. Huang
Fundamentals of statistical and thermal physics – F. Reif
Statistical Mechanics - an elementary outline – A. Lahiri
An Introductory Course of Statistical Mechanics – P. B. Pal

Paper – VIII: Quantum Mechanics I

A. General formalism: States, observables and operators in quantum mechanics, Dirac's notation, measurement, eigenstates and mixed states, expectation values, wave-packets, Ehrenfest's theorem. Basic postulates, uncertainty principle, Schrodinger's equation, co-ordinate and momentum representation. Schrodinger, Heisenberg and interaction picture, Heisenberg's equation of motion.

B. Eigenvalue problems: Three-dimensional bound state problems, particle in a box, central potentials, free particle solution in spherical polar co-ordinates, orbital angular momentum, spherical oscillator, H-atom.

C. Matrix mechanics: Linear harmonic oscillator, angular momentum, Pauli's spin-1/2 matrices, addition of angular momenta, Clebsch-Gordon co-efficients.

D. Time independent perturbation theory: Rayleigh-Schrödinger expansion; non-degenerate states, energy and state corrections in first & second order, Zeeman effect; degenerate states, Stark effect.

E. Variational Method: Rayleigh-Ritz theorem, helium atom, method of variation of coefficients, hydrogen molecule.

F. Time dependent perturbation theory: Time dependent perturbation theory, interaction picture; Constant and harmonic perturbations – transition probability, Fermi's golden rule, applications.

G. WKB Approximation: Eikonal approximation, semi-classical reduction of Schrödinger equation, WKB equation, turning points and connection formulae, bound state solutions in the WKB approximation, barrier penetration.

Books:

Quantum Mechanics – B. H. Bransden & C. J. Joachain
Quantum Mechanics, Vol. I & II – C. Cohen-Tannoudji, B. Diu & F. Laloe.
Introduction to Quantum Mechanics – D. H. Griffiths
Quantum Mechanics, Vol. I & II – A. Messiah
Modern Quantum Mechanics – J. J. Sakurai
Quantum Mechanics – S. N. Biswas
Quantum Mechanics – S. Devnathan

Paper – IX: Computational Methods in Physics II

(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 necessary)

Numerical problems:

1. Solution of nonlinear polynomials by various methods – Bisection method, False position method, Newton-Raphson method, Baristows Method.

2. Solution of a set of linear equations – Iterative methods (Jacobi method, Gauss-Seidal method) Matrix methods (matrix inversion, Gauss-elimination method, Gauss-Jordan method).
3. Matrices – Inverse matrix, Fadeev-Leverrier method for characteristic polynomial, Eigenvalue and eigenvector by Power method.
4. Statistics – Distribution functions, Moments of a distribution, Correlation function
5. Sampling of data – Straight line fitting, quadratic curve fitting.
6. Numerical Integration – Trapezoidal method, Simpson method, Gaussian quadrature
7. Numerical differentiation.
8. Lagrange interpolation and extrapolation
9. Solution of differential equations – Euler's method and Runge-Kutta method, First order and Second order.
10. Random numbers and Monte Carlo method of evaluation of integrals – Uniformly distributed, exponentially distributed and Gaussian distributed random numbers, integrations having finite and infinite limits.

Physics Problems:
1. Simple harmonic oscillator problem with and without damping effects.
2. Coupled harmonic oscillators.
3. Charge and current oscillation in an LCR circuit
4. Motion of a falling spherical object under various effects of the medium
5. Motion of a satellite.
6. Solution of Schrodinger’s equation under various standard potentials.
7. Motion of a charged particle in electric and magnetic fields.
8. Monte Carlo technique to simulate nuclear decay phenomena.
9. Monte Carlo simulation of Ising Model
10. Phase trajectory of a chaotic pendulum.
11. Buffon's needle problem

Books:

Classical FORTRAN Programming for Engg. & Scientific Applications – M. Kupferschmid
Numerical Methods – S. Balachandra Rao & C. K. Shantha
Computational Physics - FORTRAN Version – S. E. Koonin & D. C. Meredith
Numerical Recipes in FORTRAN 77: W. H. Press, S. A. Teukolsky, W. T. Vetterling, B. P. Flannery

Paper – X: Comprehensive Course I

Based on Papers I, II, III, VI, VII and VIII

Paper – XI: Comprehensive Viva-voce I

Based on topics from Paper I, II, III, VI, VII and VIII

Semester III

Paper – XII: Quantum Mechanics II

A. Symmetries: Symmetries and conservation laws in quantum mechanics, continuous symmetries, space and time translation, rotation, infinitesimal and finite transformations, Wigner-Eckart theorem, discrete symmetries, parity and time reversal.

B. 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.

C. Scattering theory: Partial wave analysis, phase shift, optical theorem, shadow scattering. Green's function in scattering theory, Born's approximation. Applications of scattering theory, Coulomb scattering.

D. Relativistic quantum mechanics: Klein-Gordon equation, Dirac equation and its plane wave solutions, orthonormalization and completeness, spin and magnetic moment of an electron, negative energy state and its interpretation. Large and small components, Pauli's theory as non-relativistic approximation, higher order corrections, central potential, H-atom. Lorentz group, transformation property of spinors, covariance of Dirac equation, construction of covariant quantities.

E. Field quantization: Limitations of ordinary quantum theory. Principle of least action & Lagrangian formulation of field theory, Noether's theorem and conserved currents. Quantization of free fields – (i) a real scalar field, (ii) a complex scalar field and (iii) the Dirac field.

Books:

Relativistic Quantum Mechanics – J. D. Bjorken & S. D. Drell

Quantum Mechanics – E. Merzbacher
Advanced Quantum Mechanics – J. J. Sakurai
Quantum Physics – S. Gasiorowicz
Quantum Mechanics – A. K. Ghatak & S. Lokanathan
Quantum Field Theory – F. Mandl & G. Shaw

Paper – XIII: Condensed Matter Physics I

A. Elementary Crystallography: Bravais lattices; unit cell, Wigner-Seitz cell, symmetry operations and classification of 2-and 3- dimensional Bravais lattices, Crystal structures, basis, crystal class, point group and space group(information only), simple crystal structures, reciprocal lattice and Brillouin zone, reciprocal lattice for SC, BCC and FCC structures, x-ray diffraction; Bragg's law; Laue diffraction; atomic scattering factor; crystal structure factor, Ewald construction, neutron diffraction; electron diffraction.

B. Lattice vibrations and thermal properties: Vibrations of monatomic and diatomic chains; acoustical and optical lattice vibrations in crystals; dispersion relation; quantization of lattice vibrations, phonon momentum, inelastic scattering of neutrons by phonons, anharmonic effects in crystals- thermal expansion and thermal conductivity.

C. 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; paramagnetism of free electrons.

D. Band theory: Bloch theorem; motion of electrons in a periodic lattice; Brillouin zones for simple latttices; 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.

E. Dielectric Properties of insulators: Static dielectric constant: complex dielectric constant; dielectric loss; classical theory of electric polarization; ferroelectricity.

F. Magnetic properties of solids: Diamagnetism; paramagnetic susceptibility; behaviour 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.

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

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

Books:

Introduction to Solid State Physics – Charles Kittel,
Solid State Physics – N.W. Ashcroft and N.D. Mermin,
Introductory Solid State Physics – H. P. Myers,
Elementary Solid State Physics – M. Ali Omar,
Crystallography applied to Solid State Physics – A. R.Verma & O.N. Srivastava
Solid State Physics – A. J. Dekker
The Power Method – Azaroff & Buerger

Paper – XIV: Nuclear and Particle Physics I

A. 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.

B. 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 process, Interaction of gamma radiation with matter – photoelectric effect, Compton scattering and pair production.

C. Nuclear interactions and nuclear reactions: Ground state of deuteron; nucleon-nucleon scattering (low energy) – spin dependence and charge independence of nuclear force. Different types of reactions, Quantum mechanical theory, Principle of detailed balance, Compound nuclear reaction – Ghosal' s experiment.

D. Particle accelerators: Betatron – principle and betatron oscillations, Principle of phase stability and phase oscillations, Synchro-cyclotron, Synchrotron and Linear accelerators, Focusing of particle beam. Fixed target and colliding beam experiments.

E. Nuclear decays: (i) Alpha decay – Gamow's theory and systematics. (ii) Beta decay – Fermi's theory – beta spectrum, selection rules for Fermi and Gamow-Teller transitions, parity non-conservation, Coulomb effects, and Wu's experiment. (iii) Gamma decay – multipole transition and selection rules.

F. Neutron physics and 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; Spherical and Cylindrical geometry.

G. Particle Physics: Detection and classification of elementary particles, pion spin, isospin and its conservation – SU(2) and SU(3) multiplets. Quantum chromodynamics – quark model, magnetic moment of nucleons, Gellman-Okubo mass formula, quark confinement, asymptotic freedom.

Books:

Physics of Nuclei and Particles, Vol. I – P. Marmien & E. Sheldon.
Atomic & Nuclear Physics, Vol. II – S. N. Ghosal.
Particle Accelerators – M. S. Livingstone & J. P. Blewett
Introduction to elementary particles – D. Griffiths
Introduction to high energy physics – D. H. Perkins
Fundamentals of Nuclear Physics – B. D. Srivastava
Nuclear Physics – K. Krane

Paper – XV: Atomic and Molecular Physics

A. One-electron atoms: Quantum states, atomic orbitals; H-atom spectrum, fine structure of H-atom, Lamb-Rutherford experiment, Lamb shift, hyperfine structure.
B. Interaction with external fields: Time dependent perturbation treatment, electric dipole approximation, stimulated and spontaneous emission, absorption coefficients, selection rules, line broadening. Normal and anomalous Zeeman effect, Paschen-Back effect, Stark effect.
C. Two-electron atoms: Spectral terms, exchange degeneracy, singlet and triplet states; LS, JJ and mixed coupling schemes.
D. Many-electron atoms: Independent particle model, central field approximation, Russel-Saunders coupling, alkali spectra, fine and hyperfine structure in alkali spectra.
E. Laser: Basic requirements, population inversion and stimulated emission, three and four level lasers, N_2, CO_2 and He-Ne lasers. Rate equation in three level system, optical resonators, mode locking, pulse lasers. Temporal and spatial coherences, line broadening, collision and Doppler broadening. Holography.
F. Molecular orbitals: Linear combination of atomic orbitaI, 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, anharmonicity, 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.

Books:

Physics of Atoms & Molecules – B. H. Bransden & C. J. Joachain
Fundamentals of Molecular Spectroscopy – C. N. Banwell & E. M. McCash
Molecular Spectra & Molecular Structure, Vol. I – G. Herzberg
Atomic & Nuclear Physics, Vol. I – S. N. Ghosal
Introduction to Quantum Mechanics – D. H. Griffiths
Laser Fundamentals & Applications – K. Thyagarajan & A. Ghatak

Paper – XVI: Laboratory 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 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 and Jamin’s interferometer.
4. To determine the Q-factor of an LCR circuit & to determine the values of unknown resistance and capacitance.
5. To find out the dielectric constant of a liquid using a transmission line.
6. To calibrate a Pirani gauge.
9. Determination of Curie temperature of a ferromagnetic material.
10. To study optical absorption of a semiconductor and determination of its band gap.
11. To study the Zeeman effect.
12. To study the high temperature superconductivity (at liquid nitrogen temperature)
13. To study the characteristics curve of G.M. Counter and to study the statistical fluctuation in cosmic ray background radiation.
14. To study the characteristics curve of G.M. Counter and to study the decay of activity of an artificially activated source.
15. To study the characteristics curve of G.M. Counter and to find out the gamma counting efficiency of G.M. Tubes.
16. To study the characteristics curve of G.M. Counter and to study the gamma absorption in lead absorber.
17. To study the characteristics curve of G.M. Counter and to study the beta absorption in Aluminum and hence to determine maximum beta energy.

18. To study the pulse height spectra of Cs-137 using a scintillator detector.
19. Measurement of the decay lifetime of the muons using Scintillation detector (organic) – TAC assembly, and to calculate the fundamental weak coupling constant.
20. To estimate the temperature of an artificial star by photometry.
21. To study the solar limb darkening effect.

Books:

Techniques of Nuclear & Particle Physics Experiments – W. R. Leo
Nuclear Physics Experiments – J. Varma
Atomic & Nuclear Physics, Vol. II – S. N. Ghosal

Semester IV

Paper – XVII: Astrophysics and Cosmology

A. General Relativity: Riemannian geometry; covariant differentiation, geodesics; Riemann Christoffel curvature tensor; Bianchi identity; Ricci tensor; curvature scalar; condition of flatness; Einstein tensor and field equations. Energy momentum tensor for dust and perfect fluid; conservation laws; principle of equivalence and general covariance; gravitational red-shift; Einstein's equations for weak fields; gravitational waves. Schwarzschild exterior solution; conditions for circular orbits; Tests for GTR; Schwarzschild singularity; event horizon and black hole; Kerr metric.
B. Astrophysics: The Sun – general features; sunspots; thermonuclear reactions; pp chain reaction, CNO cycle; solar neutrino problem. Hydrostatic equilibrium of a Newtonian star; Lane-Emden equation; steller evolution, H-R diagram, white dwarf, neutron star, pulsar.
C. Cosmology: Cosmological principle; Robertson-Walker line element, Hubble constant, Hubble's law, the deceleration parameter, density parameter, critical density. Einstein's static universe, Big bang model, relics of Big bang model, microwave background radiation.

Books:

Introduction to Cosmology – J. V. Narlikar
Modern Cosmology – S. Dodelson
Gravitation & Cosmology – S. Weinberg

Gravity – J. B. Hartle
An Introduction to Astrophysics – B. Basu
Astrophysics – K. D. Abhayankar
Introduction to relativity – J. B. Kogut

Paper – XVIII: Special paper I

Group – A: Condensed Matter Physics II

A. 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; anharmonic effects; thermal expansion and thermal conductivity for determining phonon dispersion curves.

B. 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.

C. Ferromagnetism: Exchange interaction & Heisenberg's theory of ferromagnetism; Bloch's theory of free electron ferromagnetism; collective electron theory; magnons; magnon dispersion relation (for both ferro and anti-ferromagnetic substances); Bloch's $T^{3/2}$ law; neutron scattering by magnons; Ising model

D. 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.

E. 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.

Books:

Intermediate Quantum Theory of Solids: A O E Animalu
Principles of theory of solids: J M Ziman
Quantum theory of solids: C Kittel
Elementary excitations in solids: D Pines

Quantum theory of solid state Part A and B: J Callaway
Electron energy bands in solids: J Callaway
Nuclear magnetic resonance (Advances in solid state physics series): G E Pake

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, exchange force.
B. Nucleon-nucleon (NN) scattering: Low energy NN scattering and effective range theory.
C. Nuclear models: Collective model, rotational and vibrational states, deformed nucleus, Nilsson model.
D. Microscopic theory of nuclei: Hartree-Fock theory, BCS theory and pairing; Relativistic mean field theory, Elementary Bruckner-Goldstone theory, Super-heavy nuclei, Halo nuclei.
E. NN interaction at high energy: Hadron structure, NN potentials, meson theory, Yukawa interaction, polarization in NN scattering, scattering matrix.
F. 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.
G. Cosmic Ray Physics: Origin of primary cosmic rays, acceleration of cosmic ray particles, ultra-high energy cosmic rays and extensive air-showers, energy spectrum – the knee and ankle, Greisen-Zatsepin-Kuzmin cut-off.

Books:
Theoretical Nuclear Physics – J. M. Blatt & V. F. Weisskopf
Atomic & Nuclear Physics – S. N. Ghosal, Vol. II
Nuclear Physics – R. R. Roy & B. P. Nigam
Nuclear Physics - An Introduction – H. V. Buttler
High-energy Astrophysics – M. S. Longair
Extensive Air Showers – P. K. F. Grieden, Vol. II
Structure of the Nuclei – M. A. Preston & R. K. Bhaduri
Nuclear Models – Greiner Maruhn

Group – C: Electronics II

A. Transmission lines: Voltage and current relations on radio frequency transmission line; 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; Impedance matching in high frequency lines, Impedance matching by stubs, Transmission lines as resonant circuits, Q of a transmission line; Transmission line measurements, Smith chart.

B. 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. Excitation of different modes in a wave guide.

C. Microwave Circuit components: Scattering matrix representation of microwave network, properties of S-parameter, Waveguide connectors and fittings, Microwave terminations, attenuators and phase shifters, wave guide Tees, Hybrid or Magic Tee, Directional coupler, Microwave ferrite devices, gyrator, circulator and isolator.

D. Vacuum tube- ultra high frequency and microwave oscillators: High frequency limitations of conventional vacuum tubes. Circuit reactance limitations, Electron transit time limitations, Theory of operation of magnetron, Multicavity travelling wave magnetrons, Klystron oscillators, reflex klystron, travelling-wave tubes (TWTs), backward-wave oscillators, Noise in microwave tubes.

E. Semiconductor microwave devices: Principle of negative resistance amplifier, Theory of tunnel diode amplifier, IMPATT diodes-basic principle, avalanche multiplication, parametric amplifier; Gunn- Effect oscillator-negative resistance property, domain formation, diode performance, applications.

F. Antennas: Directive gain; Radiated power and radiation resistance; Dipole antenna; Vertical antenna of different lengths; Arrays of antennas Loop, Yagi-Uda antenna, Aperture antennas, Radiation from electromagnetic horns, slot antennas, the reflector antennas.

G. 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.

Books:

Microwave Devices and Circuits – S.Y. Liao
Semiconductor Devices – S.Y. Liao
Foundation for Microwave Engineering – R. E. Collin
Radio Frequency Principles and applications – A. A Smith
Microwaves - M. L. Sisodia & V.L. Gupta
Microwave Propagation and Techniques – D. C. Sarkar

Electronics-Classical and Modern – R.K. Kar
Microwaves – K. C. Gupta
Microwave Circuits and passive Devices – M. L. Sisodia & G. S. Raghubanshi
Circuit Theory - Waveguide and Radiowave Propagation – S. N. Sen
Fiber Optics - Through Experiments – A. K. Ghatak & M.R. Shenoy
Fiber Optics Communication Systems – G. P. Agrawal
Optical Electronics – A.K. Ghatak & K. Thyagarajan
Physics of Optoelectronic Devices – S. L. Chuang
Semiconductor Optoelectronic devices – P. Bhattacharya

Paper – XIX: Special paper II

Group – A: Condensed Matter Physics III

A. Structure determination of solids: Crystal symmetry, Bravais lattice; transformation of crystal lattices; point groups; space groups; reducible and irreducible representations, character tables, space group diagrams and equivalent positions, 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; triplet phase relations, structure invariants and seminvariants, 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, colour centres; F-centers, process of creating colour centers, de Boer model, its experimental proof, Luminescence, Fluorescence and phosphorescence, physical processes following absorption of a photon, QuasicrystaJs, non-periodic long range order, Penrose tiling

B. 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 MB velocity distribution of carriers, Quantum Hall effect, 2-D electron gas system, derivation of quantum Hall resistance, compound semiconductors.

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

D. Optical properties: Drude-Lorenz theory of metals and insulators; complex dielectric constant and complex refractive indices; dispersion and absorption; reflection and absorption coeffiicients; Kramers-Kronig relations; quantum theory of optical transitions in a solid; direct and indirect, allowed and forbidden transitions; excitons; Frenkel and Mott-Wannier excitions, displacement polarizability in ionic crystals, rigid ion approximation, longitudinal and transverse optical modes, LST relation, pole and zeros of complex dielectric function, polariton, photonic crystals, dielectric mirror, effect of electric field on refractive index of anisotropic media, Pockels and Kerr effect, electro-optic modulators, Intensity modulators and optical switch, optical sacnners, semiconductor lasers, diode lasers, double heterostructure laser.

E. Phase transition and Critical Phenomena: Order parameter; Landau theory; first and second order phase transitions; critical exponents; scale invariance hypothesis; effective Hamiltonian; fluctuations of order parameter, examples of systems sharing critical behavior, Order-disorder phase transitions, Entropy of mixing in binary alloy, super lattice structure, quantum phase transitions.

F. Nanomaterials: Characterization, Limitation of optical microscopy, basics of microscopy by electron beams, scanning electron microscope, transmission electron microscopes, interaction between electrons and specimen, principle of scanning tunneling microscope, atomic force microscope.

G. Liquid crystals: Thermotropic and lyotropic liquid crystals, structure and classification of mesophases, nemartic, smectic and cholesteric phases, basic features of liquid crystal molecules, symmetries of different phases, Identification techniques – OPM, DSC and X-ray diffraction, Order parameter of nematics and smectics, Ferroelectric liquid crystals, TN display devices.

Books:

Group Theory and Quantum Mechanics – M. Tinkham
Solid State Theory – M. Sachs
X-ray structure determination – G. H. Stout and L. H. Jensen
Crystal structure Determination – M. Buerger
Intermediate Quantum Theory of Crystalline Solids – A.O.E. Animalu
Solid State Physics – N.W. Ashcroft and N.D. Mermin
Principles of the Theory of Solids – J. M. Ziman
Introduction to Solid State Physics – C. Kittel
Introduction to Liquid Crystals – P. J. Collings & M. Hird

Group – B: Nuclear and Particle Physics III

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

B. Quantum electrodynamics: Free field theory, quantization of spinor and vector fields, gauge condition, Gupta Bleuler formalism; covariant commutation relations and Feynman's propagators.

C. Interacting field theory: Covariant perturbation theory, Scattering 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, form factor.

B. Symmetries: Lie groups, Lie algebra, SU(2) & SU(3) groups. Discrete symmetries, parity transformation, charge conjugation, and time reversal – CPT theorem. Gauge theories, Yang-Mill's theory, abelian and non-abelian gauge invariance, spontaneous symmetry breaking and Higg's mechanism.

D. Relativistic Heavy-ion Interaction: MIT Bag model of a nucleus; Quark-gluon Plasma (QGP); Thermodynamics of QGP; Hydrodynamics of QGP – Bjorken's estimation of energy density; signatures of QGP – qualitative discussion.

Books:

Quantum Field Theory – F. Mandl & G. Shaw
An Introduction to Quantum Field Theory – M. E. Peskin & D. V. Schroeder
A First Book of Quantum Field Theory – A. Lahiri & P. B. Pal
Introduction to Elementary Particles – D. Griffiths
Particle Physics - A Comprehensive Introduction – A. Seiden
Quarks & Leptons – F. Halzen & A. D. Martin
Introduction to High-energy Heavy-ion Collisions – C-Y. Wong

Group – C: Electronics III

A. Electronic communication Systems: Review of modulation and detection. Noise in Amplitude Modulation(AM) systems – Double Side Band - Full Carrier (DSB-FC) Double Side Band - Suppressed Carrier (DSB-SC), Single Side Band - Suppressed Carrier (SSB-SC). Noise in angle modulated systems - FM with noise, comparison with AM system, threshold improvement through De-Emphasis. Digital communication - Pulse coded communication-Sampling theorem, PAM, PWM, PPM, PCM, Delta modulation, ASK, FSK, PSK, DPSK, QPSK, MSK. Multiple aMPC-ess techniques - Computer communication- Different networks like LAN, ISDN, PBX, Medium access sublayer-TDMA, FDMA, ALOHA Mobile communication.

B. 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.

C. Satellite communication: Satellite Communication, Orbits, Station keeping; Satellite attitude; Path loss calculation; Link calculation; Multiple access techniques; Transponders; Effects of nonlinearity of transponders.

D. Fiber optic communication: Introduction to optical fibers, wave propagation and total internal reflection in optical fiber, structure of optical fiber, Types of optical fiber, numerical aperture, acceptance angle, single and multimode optical fibers, optical fiber materials and fabrication, attenuation, dispersion, splicing and fiber connectors, fiber optic communication system, fiber sensor, optical sources and optical detectors for optical fiber.

E. 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.

F. Microprocessors and Microcontrollers:

(a)Microprocessors: Introduction to Microprocessors, Organization of Microprocessors, Signal Description of Microprocessors, Instruction Sets, Programming Techniques with Additional Instructions, Counters and Time Delays, Stack and Sub routines, Physical Memory Organization, Bus Operation, I/O Addressing Capability, Application of Microprocessors.

(b) Microcontrollers: Introduction to Microcontrollers, Embedded versus External Memory Devices, 8–bit and 16–bit Microcontrollers, CISC and RISC Processors, Harvard and Von Neumann Architectures, Commercial Microcontroller Devices.

Books:

Basics of electronic communications: NIIT
Electronic communication: Robert L. Shrader
Communication systems (analog and digital): R P Singh and S D Sapre
Electronic communication systems: George kennedy
Electronic communications: D. Roody J.Coolen Pearson
Electronics (Classical and modern): R.Kar
Fundamentals of digital circuit: Anand Kumar
Optoelectronics and fiber optics Communication: C.K.Sarkar and D.C.Sarkar
Monochrome and Color TV: Gulati

Television and Video Engineering: A. M. Dhake
Advanced Electronics: T. P. Chattopadhyay

Paper – XX: Laboratory Course 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)

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 colour centres 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) hadronic interactions, (ii) nucleus-nucleus interactions, (iii) pi-mu decay, and (iv) to measure charge of nuclear fragments in nuclear emulsion.

Books:

Techniques of Nuclear & Particle Physics Experiments – W. R. Leo
Nuclear Physics Experiments – J. Varma
Nuclear Physics, Vol. II – S. N. Ghosal
Radiation Detection & Measurements – G. F. Knoll

Group – C: Electronics

(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 4th 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 switching of a switching mode power supply.
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.
   (b) 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. Bending 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:

9. Microwave Experiments:

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

(b) To verify relationship between guide wavelength ë 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.

Books:

Experiments in Electronics – S.V. Subrahmanyam
Basic microwave Techniques and Laboratory Manual – M. L. Sisodia & G.S. Raghubanshi
Lab. Manual for Introductory Electronics Experiments – L. K. Maheshwari & M.M.S. Anand

Paper – XXI: Comprehensive Course II

Based on Papers XII, XIII, XIV, XV and XVII

Paper – XXII: Comprehensive Viva-voce II

Based on topics from Paper XII, XIII, XIV, XV and XVII