

UNIVERSITY OF DELHI
Syllabus for B.Sc. (Hons.) Physics Examination

PART I (First Year)

Paper I: Mathematical Physics I

Unit I: Vector Algebra and Analysis

- review of vector algebra: addition, subtraction and product of two vectors
- polar and axial vectors and their examples from physics
- triple and quadruple product (without geometrical applications)
- scalar and vector fields
- differentiation of a vector w.r.t. a scalar
- unit tangent vector and unit normal vector (without Frenet-Serret formulae)
- directional derivatives
- gradient, divergence, curl and Laplacian operations and their meaning
- idea of line, surface and volume integrals
- Gauss', Stokes' and Green's Theorems

Unit II: Orthogonal Curvilinear Coordinates and Multiple integrals

- derivation of gradient, divergence, curl and Laplacian in Cartesian, spherical and cylindrical coordinate systems
- change of variables and Jacobian evaluation of line, surface and volume integrals

Unit III: Differential Equations

- classification of differential equations: linear and nonlinear, homogeneous and non-homogeneous
- first order: separable and exact equations and integrating factor
- second order: homogeneous equations with constant coefficients, Wronskian and general solution, statement of Existence and Uniqueness theorem for initial value problems, solution of non-homogeneous equations by D-operator method, particular integrals, method of undetermined coefficients and variation of parameters, equations reducible to those with constant coefficients, Bernoulli and Euler equations

Unit IV: Fourier Series

- Fourier series, Dirichlet conditions (statement only)
- Orthogonality of sine and cosine functions
- sine and cosine series distinctive features of Fourier expansions
- half range expansions
- applications: square wave, triangular wave, output of full wave rectifier and other simple functions, summing of infinite series

Calculus of Variations

- constrained maxima and minima
- method of Lagrange's undetermined multipliers and its application to simple problems in Physics
- Euler – Lagrange Equation and its application to simple problems

Theory of Errors

- systematic and random errors
- propagation of errors, normal law of errors
- standard and probable error
- least square fitting of data (linear case)

Paper II: Mechanics

Unit I: Fundamentals of Dynamics

- motion of charged particle in electric and magnetic fields
- dynamics of a system of particles
- centre of mass, conservation of momentum
- idea of conservation of momentum from Newton's third law and impulse
- momentum of variable mass system: motion of rocket
- work-energy theorem
- potential energy and energy diagrams, stable and unstable equilibrium
- conservative and non-conservative forces
- force as gradient of potential energy
- particle collisions
- centre of mass frame and laboratory frame

Oscillatory Motion

- motion of simple and compound pendulum
- loaded spring
- energy considerations and time average of energy
- damped harmonic oscillator
- resonance in a lightly damped system

Unit II: Rotational Dynamics

- angular momentum of a particle and a system of particles
- torque and conservation of angular momentum
- rotation about a fixed axis
- moment of inertia: its calculation for rectangular and cylindrical bodies, and idea of calculation for spherical bodies
- kinetic energy of rotation
- motion involving both translation and rotation

Unit III: Gravitation and Central Force Motion

- law of gravitation, inertial and gravitational mass, potential energy due to spherical shell and solid sphere
- self energy motion of a particle under central force field
- angular momentum conservation
- one body problem, two body problem and its reduction to one body problem and its solution
- the energy equation and energy diagram
- Kepler's laws
- Satellites

Unit IV: Non-Inertial Systems

- inertial frames and Galilean transformations, non-inertial frames and fictitious forces
- uniformly accelerated system
- physics in rotating coordinate systems, centrifugal and coriolis forces

Special Theory of Relativity

- Michelson-Morley experiment and its outcome
- postulates of special theory of relativity
- Lorentz transformations
- simultaneity and order of events
- Lorentz contraction and time dilation
- relativistic transformation of velocity, frequency and wavenumber
- velocity dependence of mass and equivalence of mass and energy
- relativistic Doppler effect
- relativistic kinematics
- transformation of energy and momentum

Paper III: Electricity and Magnetism

Unit I: Electric Circuits

- Kirchoff's laws of AC circuits
- series and parallel resonant circuits, AC bridges
- Thevenin's theorem and Norton's theorem and their applications to DC circuits

Electric Field

- electric charge: conservation and quantization, Coulomb's law and superposition principle
- field lines
- Gauss' law
- field of linear, plane and spherical charge distribution
- line integral of an electric field
- electric potential
- potential and electric field of a dipole, a charged wire and a charged disc
- multipole expansion of potential due to arbitrary charge distribution
- force and torque on a dipole
- Laplace's equation and uniqueness theorem
- conductors in an electrostatic field
- description of a system of charged conductors
- an isolated conductor and capacitance
- method of images and its application to simple electrostatic problems: plane infinite sheet and sphere

Unit II: Electrostatic Energy

- system of point charges
- a uniform sphere
- a condenser
- an ionic crystal
- nuclear electric field; point charge

Dielectric Properties of Matter

- dielectric polarization and polarization charges
- Gauss' law dielectrics
- field vectors D and E and their boundary conditions
- capacitors filled with dielectrics

Unit III: Magnetic Field

- magnetic force between current elements and definition and properties of B
- Ampere's circuital law
- curl and divergence of B , vector potential
- magnetic flux
- calculation of B for circular and solenoidal currents
- torque on a current carrying loop in a uniform magnetic field
- magnetic dipole
- forces on an isolated moving charge

Magnetic Properties of Matter

- B , H and their relation, magnetic susceptibility
- stored magnetic energy in matter
- magnetic circuit
- B - H curve and energy loss in hysteresis

Unit IV: Electromagnetic Induction

- a conducting rod moving through a uniform magnetic field, and a loop through a non-uniform magnetic field
- a stationary loop with field source moving
- Faraday's law of induction
- mutual induction
- reciprocity theorem
- self-induction
- energy stored in magnetic field

Paper IV: Mathematics

- Sequences of real numbers: convergent, Cauchy, monotonic and bounded sequences. Subsequences. Limit superior and limit inferior of a sequence. Infinite series and their convergence. Comparison test, Cauchy's root test, d'Alembert's ratio test, Raabe's test, Cauchy's integral test. Alternating series and Leibnitz test. Absolute and conditional convergence.
- Functions of a real variable. Limits, continuity and differentiability of functions. Uniform continuity. Continuity on $[a,b]$ implying uniform continuity and boundedness. Intermediate value theorems and Taylor's theorem for analytic functions. Taylor's and MacLaurin's series of elementary analytic functions
- Functions of two and three real variables, their continuity and differentiability. Schwarz and Young's theorem. Implicit function theorem. Taylor's theorem. Maxima and minima

- Definition and examples of Riemann integral of a bounded function. Riemann integrability of continuous and monotonic functions. Riemann integral as the limit of a sum. The fundamental theorem of integral calculus. Mean value theorems
- Integration of rational and irrational functions. Integration by partial functions. Properties of definite integrals. Reduction formulae

Paper V: Chemistry

Section A

- Bonding: qualitative approach to valence bond theory and its limitations. Hybridization, equivalent and non-equivalent hybrid orbitals, Bent's rule and applications.
- Molecular orbital theory, symmetry and overlap. Molecular orbital diagrams of diatomic and simple polyatomic systems (O_2 , C_2 , B_3 , CO, NO and their ions; HCl, BeF_2 , CH_4 , BCl_3) – idea of sp^3 mixing and orbital interaction to be given

Organisation of Solids

- Packing of ions in crystals, close packed structures, spinel, ilmenite, and perovskite structures of mixed metal oxides. Size effects, radius ratio rules and their limitations. Lattice energy – Born equation (calculation of energy in ion pair and ion pairs' square formation), Madelung constant. Kapustinskii equation and its applications. Born-Haber cycle and its applications
- Solvation energy. Packing of atoms in metals, qualitative idea of valence bond and band theories. Semiconductors and insulators. Defects in solids. Conductance in ionic solids. Introduction to superconductors.
- Weak chemical forces: van der Waals forces, hydrogen bonding. Effects of chemical forces on melting and boiling points and solubility. Energetics of dissolution process

Coordination Compounds and Inorganic Reaction Mechanisms

- Crystal field theory: measurement of $10 Dq$ CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of $10 Dq$, octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral symmetry, Jahn-Teller theorem, square-planar coordination, ligand field and molecular orbital theories
- The trans effect, mechanism of trans effect, kinetics of square planar substitution reactions, thermodynamic and kinetics stability, labile and inert complexes
- Kinetics of octahedral substitution reactions, mechanism of substitution in octahedral complexes, mechanism of electron transfer reactions (inner and outer sphere mechanism)

Section B

General Organic Chemistry

- bonding in organic molecules and its effects on shape, chirality and RS nomenclature as applied to chiral centres, treatment of chirality upto three chiral centres, conformation of acyclic and cyclic systems, conformational analysis of disubstituted cyclohexanes, geometrical isomerism and E2 nomenclature

- electronic displacements in organic molecules, aromaticity, reactivity of organic molecules, heterolytic and homolytic fission, nucleophiles, electrophiles, acids and bases and their relative strengths (including carbon acids) addition, elimination and substitution reactions (including electrophile, nucleophile and aromatic types)
- arynes and carbenes as reaction intermediates

Functional Group Chemistry

- rationalization of functional group reactivity on mechanistic basis of the following groups: hydroxyl, carbonyl, carboxyl and its derivatives such as ester and amide, cyano, nitro and amino, orientation effect in aromatic substitution, polymerization and overview of polymers, organic reactions as synthetic tools, Claisen, Cannizzaro, Grignard, Michael, Mannich, Darzen, aldol, Diekmann, Perkin reactions.

Paper VI: Linear and Digital Integrated Circuits and Instruments

Unit I: Basic Concepts of Integrated Circuits

- active and passive components, discrete component circuits, wafer, chip, advantages of integrated circuits
- MSI, LSI, VLSI (basic ideas and definitions only)

Op-Amps

- basic characteristics without detailed internal circuit of IC: requirement of ideal voltage amplifier, characteristics of ideal op-amp, feedback in amplifier (black box approach), open loop and close loop gain, inverting and non-inverting amplifier, zero crossing detector
- applications: mathematical operations such as addition, multiplication, integration and differentiation, electronic circuits such as Wien bridge oscillator, rectangular and triangular wave generators (all circuit analysis based on Kirchoff's laws)

Unit II: Digital Circuits

- difference between analog and digital circuits, binary numbers, binary to decimal conversion, AND, OR and NOT gates (realization using diodes and transistor), Boolean algebra, Boolean equations of logic circuits, de Morgan theorem, NOR and NAND gates
- combinational logic: Boolean laws and theorems, sum of products, method of realizing a circuit for a given truth table, truth table to Karnaugh map and simplification (elementary idea)
- data processing circuits: multiplexers, demultiplexers, decoders, encoders, exclusive OR gate, parity checker, read-only memories (ROM, PROM, EPROM).
- Arithmetic circuits: binary addition and subtraction (only 2's complement method), half adders and full adders and subtractors

Unit III

- sequential circuits: flip-flops – RS, JK, D, clocked, preset and clear operation, race-around conditions in JK flip-flop, master slave JK flip-flop as building block of sequential circuits

- shift registers: serial in serial out, serial in parallel out, parallel in parallel out (only upto 4 bits)
- counters: asynchronous counters, synchronous counter, decade counter
- D/A and A/D conversion, D/A converter – resistive network, accuracy and resolution, A/D converter – counter method, accuracy and resolution

Unit IV: Electronic Instruments

- timer: simple applications of 555 timer circuits
- power supply: requirement of ideal voltage and current source, voltage source, half-wave and full-wave rectifier, bridge rectifier, L and C filters, ripple
- oscilloscope: input attenuators, DC, AC, and ground, horizontal and vertical deflecting system, time base generation and synchronization, measurement of positive, positive-negative wave shape, rise time and fall time; frequency, amplitude and phase of sinusoidal waves

Paper VII: Physics Laboratory I

Unit I: Methodology and Familiarisation

1. Measurement of length using: crude estimation, ungraduated and graduated scales, triangulation method, vernier calipers, screw gauge, traveling microscope, indirect methods like for estimation of atomic size
2. Familiarisation with basic electronic components
3. Familiarisation with operation of basic measuring and test equipment (power supplies, analog and digital multimeters, function generator and CRO)
4. To test a diode and transistor using multimeter and CRO

Unit II

1. To study the random error in observations
2. Experiments for generation of data in linear and non-linear regions for the following systems: flow of liquid through capillary tube, diode characteristics, pendulum with large amplitude
3. Frequency and phase measurements using CRO
4. Spring constant and mass from vertical oscillations of a spring and determination of modulus of rigidity.

Unit III: Electronics and Instrumentation

1. To design an amplifier of given gain using op-amp 741 in inverting and non-inverting configurations and to study its frequency response
2. To design a precision differential amplifier of given I/O specification using 741
3. To design an astable oscillator of given specifications using 555.
4. To design a monostable oscillator of given specifications using 555.

Unit IV: Measurement of R and V

1. Precise measurement of a low resistance using Carey-Foster's bridge potentiometer
2. To calibrate a resistance temperature device (RTD) to measure temperature in a specified range using null method/off-balance bridge with galvanometer based measurement

3. To calibrate a thermocouple to measure temperature in a specified range using null method/direct measurement using an op-amp difference amplifier and to determine neutral temperature.

Unit V: Mechanics

1. To determine the acceleration due to gravity using compound pendulum
2. To determine the acceleration due to gravity using Kater's pendulum.
3. To determine the acceleration due to gravity and velocity for a freely falling body, using digital timing techniques.

Unit VI: Oscillators

1. To investigate the motion of a simple or physical pendulum with: variation of moment of inertia, and viscous frictional and electro-magnetic damping
2. To investigate the motion of coupled oscillators
3. To investigate the forced oscillations of an LCR circuit in series and parallel configurations and calculate quality factor Q

Paper VIII: Chemistry Laboratory

1. Separation of cations and anions by paper chromatography
2. preparation of:
 - i) manganese(III)phosphate. Estimation of Mn content in the above complex colorimetrically (periodate oxidation). Estimation of oxidizing equivalents in the above complex by titration of liberated iodine
 - ii) tetrammine copper(II)sulphate and estimation of copper as CuCNS gravimetrically in the above complex
3. preparation of:
 - i) aspirin
 - ii) hippuric acid (benzoylglycine)
 - iii) methyl orange or phenolphthalein: characterization by mp, and TLC
4. two-step preparations
 - i) nitrobenzene from benzene, purification of nitrobenzene and characterization by refractive index, further nitration
 - ii) p-bromoacetanilide from aniline
5. preparation of lactose and casein from milk or isolation of caffeine from tea leaves (mp, colour test)
6. estimation of glucose, saponification value or iodine value of a fat or oil
7. potentiometric titration of Mohr's salt with $K_2Cr_2O_7$ or $KMnO_4$ using digital multimeter or low cost potentiometer
8. conductometric titration of a solution of HCl or CH_3COOH with NaOH by a direct reading conductometer
9. Determination of molecular mass of a polymer by measurement of viscosity
10. the effect of detergent on the surface tension of water (variation of surface tension with concentration to be studied)
11. determination of the rate law for one of the following reactions:
 - i) persulphate-iodide reaction

- ii) iodination of acetone
12. To study the kinetics of inversion of cane sugar (polarimetrically).

Paper Q1: Qualifying English

For the detailed course of Qualifying English, please see the syllabus for BA (pass), B.Com (pass) and subsidiary Qualifying English.

PART II (Second Year)

Paper IX: Mathematical Physics II

Unit I: Complex Variables

- importance of complex numbers and their graphical representation, De Moivre's theorem, roots of complex numbers, Euler's formula, functions of complex variables, Cauchy-Riemann conditions, analytic functions, singularities, differentiation and integration of a function of a complex variable, Cauchy's theorem, Cauchy's integral formula, Morera's theorem, Cauchy's inequality, Liouville's theorem, fundamental theorem of algebra
- multiple valued functions, simple ideas of branch points and Riemann surfaces, power series of a complex variable, Taylor and Laurent series, residue and residue theorem

Unit II:

- contour integration and its application to evaluation of integrals
- series solution of linear second order ordinary differential equations
- singular points of second order differential equations and their importance, series methods (Frobenius), Legendre, Bessel, Hermite and Laguerre differential equations

Unit III: Special Functions

- gamma and beta functions
- Legendre, Hermite and Laguerre polynomials, Rodrigues formula generating functions, recurrence relations, orthogonality
- Series expansion of a function in terms of a complete set of Legendre functions
- Bessel functions: first and second kind, generating function, recurrence formulae, zeros of Bessel functions and orthogonality, Fraunhofer diffraction integral for circular aperture

Unit IV: Partial Differential Equations

- generating solution of wave equation in 1 dimension, transverse vibration of stretched string, oscillation of hanging chain, wave equation in 2 and 3 dimensions, vibrations of rectangular and circular membrane
- derivation of the equation of heat conduction, heat flow in 1, 2 and 3 dimensional rectangular systems of finite boundaries, temperature inside circular plate

- Laplace's equation in Cartesian, cylindrical and spherical coordinates, problems of steady flow of heat in rectangular and circular plate, gravitational potential of a ring.

Paper X: Thermal Physics

Unit I: Kinetic Theory of Gases

- derivation of Maxwell's law of distribution of velocities and its experimental verification, mean free path, transport phenomena
- viscosity, conduction and diffusion, Brownian motion, the theories of Langevin and Einstein and experimental determination of Avogadro's number
- examples of Brownian motion in physics (galvanometer mirror, sedimentation, Johnson's noise)

Unit II:

- ideal gases: equation of state, internal energy, specific heats, entropy, isothermal and adiabatic processes, compressibility and expansion coefficient, adiabatic lapse rate
- real gases: deviations from the ideal behaviour, the virial equation, Andrew's experiments on carbon dioxide gas, continuity of liquid and gaseous state, van der Waal's equation, critical constants and law of corresponding states, free expansion, Joule-Thomson effect

Unit III: Thermodynamics

- zeroth and first law of thermodynamics, reversible and irreversible processes, conversion of heat into work, Carnot theorem, second law of thermodynamics, thermodynamic temperature, Clausius inequality
- entropy, entropy changes in reversible and irreversible processes, temperature-entropy diagrams, the principle of increase of entropy applications

Unit IV:

- thermodynamic potentials: enthalpy, Gibbs and Helmholtz functions, Maxwell relations and their applications
- magnetic work, magnetic cooling by adiabatic demagnetization, approach to absolute zero
- change of phase, equilibrium between a liquid and its vapour, Clausius-Clapeyron equation, the triple point with examples from physics, second order phase transitions

Paper XI: Vibrations and Wave Optics

Unit I: Vibrations

- free oscillations of system with one degree of freedom, linearity and superposition principle of two and N-collinear harmonic oscillations, beats
- systems with two degrees of freedom (coupled oscillators), normal coordinates and normal modes

- energy relation and energy transfer, normal modes of N coupled oscillators
- normal modes of stretched string, energy of vibrating string, plucked struck strings

Waves

- wave equation, traveling waves, plane and spherical waves, superposition of two harmonic waves, standing waves on a string, superposition of N harmonic waves, pulses and wave packets

Unit II: Wave Optics

- introduction of different models, light waves, electromagnetic nature of light waves
- coherence and interference
- interaction of independent light sources, classification in terms of division of amplitude and division of wavefront, Young's double slit experiment, Lloyd's mirror and Fresnel's biprism, interference in thin films: parallel and wedge shaped films, fringes of equal inclination (Haidinger fringes) and fringes of equal thickness (Fizeau fringes)
- Michelson's interferometer: theory, form of fringes (mention only), applications, visibility of fringes
- Theory of partial coherence, coherence time and coherence length i.e. temporal and spatial coherence
- Fabry-Perot interferometer: theory, Airy's formula, sharpness of fringes, finesse, visibility of fringes

Unit III: Diffraction

- Kirchhoff's integral theorem, Fresnel-Kirchhoff integral formula and its application to diffraction problems
- Fraunhofer diffraction: single slit, rectangular and circular aperture, multiple slit, plane diffraction grating, resolving power and dispersive power of a plane diffracting grating

Unit IV

- Fresnel diffraction: Fresnel's integrals, Cornu's spiral, Fresnel diffraction pattern at a straight edge, a slit and a wire (qualitatively using Cornu's spiral)
- Holography: principle of holography, recording and reconstruction method and its theory as interference between two plane waves

Paper XII: Quantum Mechanics and Nuclear Physics

Unit I: Particles and Waves

- photoelectric effect, Compton effect, reduced mass correction, De Broglie hypothesis, wave particle duality
- Davisson-Germer experiment, wave packets, two slit experiment with electrons
- Probability, wave amplitude and wave functions, uncertainty principle

Quantum Mechanics

- basic postulates and formalism: Schrodinger's equation, wave function, eigenvalues, probabilistic interpretation, conditions for physical acceptability of wave functions, free particle

- time independent Schrodinger equation, stationary states, particle in one dimensional box, quantization of energy, Franck-Hertz experiment

Unit II:

- scattering problem in one dimension: reflection and transmission by a finite potential step. Stationary solutions, attractive and repulsive potential barriers, Gamow theory of alpha decay, quantum phenomenon of tunneling, tunnel diode-qualitative description, spectrum for a square well (mention upper bound – no calculation)
- bound state problems: general features of a bound particle system, one dimensional simple harmonic oscillator, particle in a spherically symmetric potential rigid rotator, orbital angular momentum and azimuthal quantum numbers and space quantization, physical significance, radial solutions and principle quantum number, Hydrogen atom

Unit III:

- atoms in electric and magnetic fields: electron spin, Stern-Gerlach experiment, orbital angular momentum, magnetic dipole moment and energy in magnetic field from classical viewpoint, Zeeman effect, spin-orbit coupling, fine structure, total angular momentum
- many electron atoms: Pauli exclusion principle, many particles in one dimensional box, symmetric and anti-symmetric wave functions, atomic shell model and periodic table, spectral notations for atomic states, vector model LS and JJ coupling, doublet structure of alkali spectra, empirical evidence of multiplets, selection rules

Unit IV: Nucleus

- properties: mass, size, angular momentum, constituents binding, energy, stability
- models: liquid drop model, mass formula, shell model Nuclear forces
- radioactivity: law of radioactive decay, theory of successive radioactive transformations, radioactive series

Paper XIII: Mathematics II

Analysis

- sequences and series of functions of real variable, pointwise and uniform convergence, Weierstrass M-test, uniform convergence and continuity, uniform convergence and differentiation, uniform convergence and integration, Weierstrass approximation theorem, power series and their convergence and uniform convergence, definition of exponential, logarithmic and trigonometric functions by means of power series
- improper integrals and their convergence, comparison, Abel's and Dirichlet's tests, beta and gamma functions and their properties, differentiation under the sign of integration

Statistics

- probability classical, relative frequency and axiomatic approaches to probability, theorems of total and compound probability, conditional probability, independent

- events, Baye's theorem, random variables, discrete and continuous random variables, distribution function, expectation of a random variable, moments, moment generating formation and probability generating function
- discrete and continuous distribution binomial, Poisson, geometric, normal and exponential distributions, bivariate distribution, conditional distribution and marginal distribution, correlation and regression for two variables only, weak law of large numbers, central limit theorem for independent and identically distributed random variables
 - statistical interference, definitions of random sample, parameter and statistic concept of sampling distribution and random error, sampling distribution of mean variance of random sample from a normal population, test of significance based on F and chi-square distributions

Paper XIV: Computer Fundamentals and Programming

Unit I:

- basic components of computer system, their function and interrelation, types of computer systems
- brief idea of data storage and input/output devices, hexadecimal number system and arithmetic

Microprocessor Architecture and Operations (Intel 8085/8086)

- basic concepts, pin-out, functional block diagram, memory, memory organization and addressing, memory interfacing, memory map, ALU, registers, bus, timing and control circuitry, interrupts, I/O, instruction cycle (timing diagram)
- microprocessor programming: algorithm and flowcharts, assembly language, 8085 instruction set and format, data transfer, arithmetic, logical and control operations, RIM and SIM addressing modes (register, immediate, direct and indirect), simple programming exercises (addition and multiplication, both 8 and 16 bit etc)

Unit II: Problem Solving Using Pascal

- algorithms and flowcharts, structured programming, fundamentals of Pascal data types, constants and variables, expressions and statements, I/O commands control statements, unconditional/conditional looping
- arrays (vectors and matrices), sub-programs (functions and procedures), programming exercises based on the above-roots of a quadratic equation, least square fitting of data, sorting of numbers, prime numbers, sum and average, largest of n numbers, sorting a list in ascending/descending order, manipulations of tables (sum, product, inverse of matrices), generation of random numbers, factorials etc.
- basic idea of records, files, sets and pointers

Unit III: Errors and Iterative Methods

- truncation and round-off errors, floating point computation, overflow and underflow, single and double precision arithmetic, iterative process, solution of

- non-linear equations: bisection, secant and Newton-Raphson methods, comparison and error estimation, program for finding zeroes of a given function
- solution of simultaneous linear equations: Gauss elimination and iterative (Gauss-Seidel) method, computation of eigenvalues and eigenvectors of matrices using iterative process, program for finding solution – a given system of three coupled linear equations

Unit IV: Numerical Differential and Integral Calculus

- interpolation (Newton forward and backward formulas), program for (a) interpolating data point and (b) first and second derivative of a given function/data
- integration: general quadrature formula, trapezoidal and Simpson's rule, Gauss quadrature formulas: Gauss-Hermite, Gauss-Legendre, program for integrating a given function using Simpson and Gauss-Legendre methods
- solution of ordinary differential equations: Euler method and Runge-Kutta method of second order with error estimation, idea of predictor-corrector method, program for solving initial value problems for a first order differential equation using Runge-Kutta method

Paper XV: Physics Laboratory II

Unit I: Familiarization with devices

- measurement of focal length of a lens, combination of lenses, familiarization with eye-pieces
- familiarization with spectrometer: Schuster's method, determination of angle of prism
- familiarization with ballistic galvanometer: determination of charge sensitivity, current sensitivity, time period, logarithmic decrement and critical damping resistance
- investigation of factors which affect induced voltages in a coil using a CRO
- investigation of factors which determine secondary emf and current in coupled coils

Unit II: Optics

- experiments on prism: resolving power, dispersive power, determination of wavelength/Cauchy's constants
- experiments on grating: resolving power, dispersive power, determination of wavelength
- determination of wavelength using Fresnel's biprism
- determination of wavelength using Newton's rings
- determination of wavelength using Michelson's interferometer
- measurement of small thickness using interference or diffraction
- measurement of refractive index of transparent and opaque liquids using total internal reflection
- measurement of intensity using photosensor and laser in diffraction patterns of single and double slits

Unit III: Measurement of High Resistance and Charge

- determination of dielectric constant of a dielectric placed inside a parallel plate capacitor using a BG
- measurement of charge by determination of time of impact
- measurement of high resistance by method of leakage

Unit IV: Measurement of Self Inductance and Mutual Inductance

- using absolute method
- using AC bridge

Unit V: Measurement of Temperature

- determination of heat conductivity of a good conductor by Angstrom method/Searle's method
- determination of heat conductivity of a bad conductor by Lee's method. (use of heating elements in preference to steam recommended)

Paper XVI: Digital Electronics, Microprocessor and Computer Laboratory

Unit I: Combinational Logic

- verification and design of AND, OR, NOT and XOR gates using NAND gates
- to design, a combinational logic system for a specified truth table
- to convert a Boolean expression into a logic gate circuit and assemble it using logic gate ICs
- to minimize a given logic circuit
- to study TTL ICs (binary decoder, 7segment decider, Schmitt trigger)
- to design a 7-segment display driver

Unit II: Arithmetic and Logic Units (ALU)

- half adder, full adder, and 4 bit binary adder
- half subtractor, full subtractor, adder subtractor using full adder IC

Unit III: Flip-Flops, Counters and Shift Registers

- to build a flip flop circuits using elementary gates (RS, clocked RS, D-type, JK)
- to build a 4 bit counter using D-type JK flip-flop
- to make a shift register from D type flip-flop
- serial and parallel shifting of data

Unit IV: Analog/Digital Conversion

- to design an A/D converter
- to design a D/A converter

Unit V: Use of Microprocessor Kit and Elements of Assembly Language

- use of hardware
- addition and subtraction of numbers using direct and indirect addressing modes
- multiplication by repeated addition
- division by repeated subtraction
- handling of 16bit numbers
- use of CALL and RETURN instruction
- block data handling
- other exercises (parity check etc)

Unit VI: Elements of Pascal Programming

- to evaluate a polynomial (like converting Fahrenheit to Celsius, area of a circle, volume of a sphere etc)
- to find roots of a quadratic equation (real and distinct, real and repeated and imaginary)
- to find sum and average of a list of numbers, both with and without the use of arrays
- to calculate powers of a number
- to locate a number in a given list (linear search), to check whether a given name is in a list
- to find the largest of three numbers, to find the largest number in a given list of numbers
- to check whether a given number is a prime number, to calculate the first 100 prime numbers
- to rearrange a list of numbers in ascending and descending order
- to calculate factorial of a number, to calculate the first factorials
- manipulation of matrices: addition, subtraction and multiplication, trace of a matrix, sum of elements of a row and a column
- solution of simultaneous equations
- programming exercises based on numerical methods

PART III (Third Year)

Paper XVII: Mathematical Physics III

Unit I: Linear Vector Spaces and Matrices

- introduction to groups, rings and fields
- vector spaces and subspaces, linear independence – basis and dimensions, linear transformations, algebra of linear transformations, non-singular transformations, isomorphism, representation of linear transformations by matrices
- special matrices: Hermitian and skew-Hermitian, symmetric and anti-symmetric, orthogonal and unitary matrices, similarity transformations and bilinear and quadratic forms, trace of a matrix, Cayley-Hamilton theorem, function of a matrix
- metric spaces, inner product and metric concept

Unit II:

- matrix algebra addition and multiplication, null and unit matrices, singular and non-singular matrices, inverse of a matrix, eigenvalues and eigenvectors diagonalisation, solution of coupled linear ordinary differential equations.

Unit III: Cartesian Tensors

- transformation of coordinates, tensorial character of physical quantities, symmetric and anti-symmetric tensors, contraction and differentiation pseudotensors Kronecker and alternating tensors, higher order alternating tensors using determinants, stress and strain tensor, elasticity tensor, moment of inertia tensor

Unit IV: Integral Transforms

- step function and Dirac delta function
- Fourier transform, Fourier integral theorem, sine and cosine transforms, convolution theorem, solution of one dimensional diffusion and wave equations, heat flow in an infinite and semi-infinite rod
- Laplace transform: transform of elementary functions, derivatives and integrals, unit step function, periodic functions, translation, substitution and convolution theorem, inverse transform (Bromwich integral), solution of first and second order ordinary differential equations with constant coefficients and simultaneous first order ordinary differential equations, solution of partial differential equations
- Evaluation of integrals using transforms

Paper XVIII: Electromagnetic Theory

Unit I:

- Maxwell equations, displacement current, vector and scalar potentials, gauge transformations: Lorentz and Coulomb gauge, boundary conditions at interface between different media, wave equations, plane waves in dielectric media
- Poynting theorem and Poynting vector, energy density, physical concept of electromagnetic field momentum density and em field angular momentum density

Unit II:

- reflection and refraction of a plane wave at a plane interface between dielectrics, Fresnel formula, total internal reflection, Brewster's angle, waves in conducting media metallic reflection (normal incidence), skin depth
- Maxwell's equations in microscopic media (plasma), characteristic plasma frequency, refractive index, conductivity of an ionized gas, propagation of em waves in ionosphere

Unit III:

- polarization of em waves, description of linear circular and elliptical polarization
- propagation of em waves in anisotropic media, symmetric nature of dielectric tensor, Fresnel's formula, light propagation in uniaxial crystal, double refraction, Nicol prism, production of circularly and elliptically polarized light, Babinet compensator, analysis of polarized light

Unit IV:

- wave guides coaxial transmission lines, modes in rectangular wave guide, energy flow and attenuation in wave guides, rectangular resonant cavities
- planar optical wave guides, planar dielectric wave guide, condition of continuity at interface phase shift on total reflection, eigenvalue equations phase and group velocity of the guided waves, field energy and power transmission, optical fibre-numerical aperture, step index and graded index, single mode and multiple mode fibres

Paper XIX: Statistical Physics

Unit I: Classical Statistics

- entropy and thermodynamic probability, Maxwell-Boltzmann distribution law, partition function, thermodynamic functions of finite number of energy levels, negative temperature, thermodynamic functions of an ideal gas, classical entropy expression, Gibbs paradox, law of equipartition of energy, applications to specific heat and its limitations

Unit II: Classical Theory of Radiation

- properties of thermal radiation, Kirchhoff's law, Stefan-Boltzmann law and Wien's displacement law, Saha's ionization formula

Quantum Theory of Radiation

- Planck's law of black body radiation, deduction of Wien's radiation formula, Rayleigh-Jeans law, Stefan-Boltzmann law and Wien's displacement law from Planck's law
- Laser working principle, thermal equilibrium of radiation, principle of detailed balance Einstein's A and B coefficients, population inversion, two level and three level systems

Unit III: Bose-Einstein Statistic

- B-E distribution law, thermodynamic functions of an ideal weakly degenerate gas, strongly degenerate Bose gas, Bose-Einstein condensation properties of liquid He (qualitative description), radiation as photon gas, Bose's derivation of Planck's law, thermodynamic functions of photon gas
- Specific heat of hydrogen: quantization of rotational and vibrational motion, ortho and para hydrogen

Unit IV: Fermi-Dirac Statistics

- Fermi-Dirac distribution law, Fermi energy, thermodynamic functions of an ideal weakly degenerate Fermi gas, strongly degenerate Fermi gas, electron gas in a metal, specific heat of metals, Richardson's equation of thermionic emission, relative Fermi gas, white dwarf stars, Chandrasekhar mass limit
- Third law of thermodynamics, absolute definition of entropy, consequences of third law, unattainability of absolute zero

Paper XX: Physics of Materials

Unit I: Crystal Structure

- amorphous and crystalline materials
- lattice translation vectors, lattice with a basis-central and non-central elements, unit cell, reciprocal lattice, types of lattices, crystal diffraction: Bragg's law, diffraction of X-rays, atoms and geometrical structure factor
- X-ray diffraction methods, measurement of lattice parameter for cubic lattices

Unit II: Elementary Lattice Dynamics

- lattice vibrations, linear monoatomic and diatomic chains, acoustical and optical phonons, qualitative description of the phonon spectrum in a solid, Brillouin zones, Einstein and Debye theories of specific heat of solids. T^3 law

Magnetic Properties of Matter

- response of substances of magnetic field, dia-, para-, and ferri- and ferromagnetic materials, classical Langevin theory of dia and paramagnetic domains, quantum mechanical treatment of paramagnetism, Curie's law, Weiss' theory of ferromagnetism and ferromagnetic domains and discussion of BH hysteresis, qualitative discussion of ferrimagnets and ferrites

Unit III: Dielectric Properties of Materials

- polarization, local electric field at an atom, depolarization field, Lorentz fields of dipoles inside a cavity
- dielectric constant and polarizability: electric susceptibility, polarizability, Clausius-Mosotti equation, classical theory of electronic polarizability, normal and anomalous dispersion, Cauchy and Sellmeier relations, orientational polarizability and Langevin-Debye equation, complex dielectric constant, dielectric constant and loss, qualitative discussion of ferroelectric properties of materials and PE hysteresis loop

Unit IV: Electrical Properties of Materials

- qualitative description of free electron theory and its inadequacies with reference to Hall effect and specific heat of electrons in a metal
- elementary band theory, Bloch theorem, Kronig-Penney model, effective mass of electron, concept of hole, band gaps, difference between conductors, semiconductors and insulators, intrinsic and extrinsic semiconductors, p- and n-type semiconductors, law of mass action, conductivity in semiconductors, mobility of carriers (lattice and impurity scattering), Hall effect in semiconductors

Superconductivity

- experimental properties, Meissner effect, type I and type II superconductors, London's equation and penetration depth.

Paper XXI: Electronic Devices: Physics and Applications

Unit I:

- mesh analysis of DC and AC circuits, nodal analysis, duality in networks, T equivalent of a four terminal network, Thevenin and Norton theorems, maximum power transfer, superposition and reciprocity theorems, Z, Y, H parameters
- basic semiconductor physics, p- and n- type, energy level diagram, conductivity and mobility, pn junction fabrication (simple idea), barrier formation in pn junction diode, current flow mechanism in forward and reverse biased diode (recombination, drift and saturation of drift velocity), derivation of mathematical equations for barrier potential, barrier width and current for step junction

Unit II A:

- single pn junction device (physical explanation, current voltage characteristics and one or two applications), two terminal devices – rectifier diode, Zener diode,

- photo diode, LED, solar cell and varactor diode, three terminal devices – junction field effect transistor (FET), unijunction transistor (UJT) and their equivalent circuits
- two junction devices – p-n-p and n-p-n transistors, physical mechanism of current flow, active, cutoff, and saturation regions, transistor in active region and equivalent circuit

Unit III:

- amplifiers – only bipolar junction transistor, CB, CE and CC configurations, single stage CE amplifier (biasing and stabilization circuits, Q point, equivalent circuit, input impedance, output impedance, voltage and current gain), class A, B, C amplifiers (definitions), RC coupled amplifiers (frequency response, bode plot, amplitude and phase), class B push-pull amplifier
- feedback in amplifiers – voltage feedback and current feedback, effect of negative voltage series feedback on input impedance, output impedance and gain, stability, distortion and noise

Unit IV:

- oscillators – Barkhausen criterion, Colpitts, phase shift and crystal oscillators
- multivibrators and sweep circuit, basic circuits of astable, bistable and monostable multivibrators, details of astable multivibrators (derivation of time period), sweep circuit using transistor as a switch and UJT (derivation of time period)

Unit II B:

- modulation and detection – basic concepts of amplitude, frequency and phase modulations and demodulation, detailed circuit of CE amplitude modulator and diode detector

Paper XXII (Option 1) : Modern Chemistry

Quantum Chemistry

- a review of Schrodinger equation, quantum mechanical operators (eg. Hamiltonian), solution of Schrodinger equation for single particle system, electron spin, Pauli exclusion principle
- quantum mechanics of polyelectronic systems (atoms and molecules), the He atom self-consistent field method (qualitative account), the variation theorem – its statement and use, chemical bonding, valence bond and molecular orbital approaches, the LCAO treatment of H_2^+ and H_2 molecules, valence bond treatment of H_2
- bonding in heteroatomic diatomic molecules (eg. HF), triatomic molecules (BeH_2 , H_2O), polyatomics, pi-electron theory (Huckel theory) for conjugated systems (eg. Butadiene)

Molecular Spectra

- em radiation, quantization of different forms of energies in molecules (translational, rotational, vibrational, and electronic), interaction of em radiation with molecules, various types of spectra, Born-Oppenheimer approximation

Rotational Spectra

- rigid rotator model, rotational spectra, intensity of spectral lines and determination of bond distance of diatomic molecules, isotopic substitution

Vibrational Spectra

- vibrational energies of diatomic molecules, zero point energy, evaluation of force constant and stiffness of the bond, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, concept of group frequencies

Raman Spectra (Qualitative Treatment)

- Raman effect, rotational Raman spectra, vibrational Raman spectra, Stokes and anti-Stokes lines and their intensity difference, rule of mutual exclusion

Electronic Spectra

- Frank-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation, calculation of electronic transitions of polyene using free electron model (particle in a box)
- NMR: principle, Larmor precession, chemical shift and low resolution spectra and scales, spin-spin coupling and high resolution spectra (interpretation of PMR spectra of A-X type organic molecules)
- ESR: principle, hyperfine structure, ESR of simple radicals (methyl radical, vanadyl ion)

Paper XXII (Option 3): Economics

Microeconomics

- the theory of consumer behaviour: utility function and demand function, substitution and income effects, the Slutsky equation, the theory of revealed preference, consumer surplus, the expenditure and the indirect utility functions
- the theory of the firm: the production function, constrained output maximization and cost minimization, cost function, the short run and the long run
- market structures: perfect competition, monopoly, monopolistic competition, duopoly and oligopoly
- general equilibrium theory: the existence of equilibrium stability and uniqueness of the equilibrium
- welfare economics: Pareto optimality and the effect of perfect competition, social welfare functions, utilitarianism and equity

Macroeconomics

- national income accounting: the concepts of Gross National Product, Net National Product and other macro aggregates, real and nominal GNP
- the simple Keynesian model: equilibrium level of income and output. The consumption function, saving and investment, the multiplier
- money, interest and income: the product market and the money market equilibrium, the role of monetary and fiscal policy in macroeconomic management

- macroeconomics in an open economy: trade and capital flows under fixed and flexible exchange rates, the monetary approach to the balance of payments, devaluation

Econometrics

- problems of estimation and inference in the two-valued linear regression model
- multiple regression-estimation and interpretation tests and test of the general linear hypothesis
- violations of the classical assumptions multicollinearity, serial correlation, heteroscedasticity

Paper XXIII: Physics Laboratory III

Unit I: Measurement of Magnetic Field and Related Parameters

- measurement of field strength B and its variation in a solenoid (determination of dB/dx)
- determination of B-H curve using ballistic galvanometer
- determination of magnetic susceptibility for liquids and solids

Unit II: Polarisation

- polarization of light by simple reflection (determination of variation of percentage reflection and degree of polarization with angle of incidence)
- determination of specific rotation for cane sugar solution
- study of elliptically polarized light

Unit III: Determination of Fundamental Constants

- determination of Boltzmann constant by studying forward characteristics of a diode
- determination of e/m by method of magnetic focusing or bar magnet
- determination of Stefan's constant

Unit IV: Measurements in Solid State Physics

- measurement of resistivity as a function of temperature for a Ge crystal using four probe method (from room temperature to 200 C) and determination of energy gap
- determination of Hall coefficient of a given sample
- determination of PE hysteresis of a ferroelectric crystal
- measurement of magnetic susceptibility

Unit V: Miscellaneous

- ultrasonic grating
- determination of wavelength of H-alpha emission line of hydrogen atom
- determination of absorption lines in the rotational spectrum of iodine vapour

Paper XXIV: Physics Laboratory IV

Unit I: Power Supply

- to design a semiconductor power supply of given rating using half wave a full wave or bridge rectifier and investigate the effect of C-filter
- to investigate simple regulation and stabilization circuits using Zener diodes and voltage regulator ICs

Unit II: Transistor Applications

- to study the various transistor biasing configurations
- to design a CE amplifier of a given gain (midgain) using voltage divider bias
- to design an oscillator of given specifications
- to study, the characteristics of a FET and design a common source amplifier

Unit III: Op-Amp

- to investigate the use of an op-amp as an integrator
- to investigate the use of an op-amp as a differentiator
- to design an analog circuit to simulate the solution of a first/second order differential equation
- to design an op-amp oscillator

Unit IV: Modulation

- to study amplitude modulation using transistor
- to study a crystal rectifier
- to study pulse width/pulse position and pulse amplitude modulation using ICs

Unit V: Multivibrators and Sweep Circuits

- to study the characteristics of a UJT and design a simple relaxation oscillator
- to design an astable multivibrator of give time period (millisecond order)
- to design a sweep of given amplitude and time

Unit VI: Transducers

- to determine the coupling coefficient of a piezo-electric crystal
- to determine the characteristics of a pn junction of a solar cell
- to study the characteristics of a photo diode

Unit VII: Networks

- to verify the Thevenin, Norton and maximum power transfer theorems
- measurement of input and output impedance of an unknown network and making equivalent T an pi circuits