

Physical Science:

Existing Syllabus	Proposed Syllabus
<p>1. Mathematical Methods of Physics</p> <p>Dimensional analysis. Vector algebra and vector calculus. Linear algebra, matrices, Cayley-Hamilton Theorem. Eigenvalues and eigenvectors. Linear ordinary differential equations of first & second order. Special functions (Hermite, Bessel, Laguerre and Legendre functions). Fourier series, Fourier and Laplace transforms. Elements of complex analysis, analytic functions; Taylor & Laurent series; poles, residues and evaluation of integrals. Elementary probability theory, random variables, binomial, Poisson and normal distributions. Central limit theorem.</p> <p>II. Classical Mechanics</p> <p>Newton's laws. Dynamical systems, Phase space dynamics, stability analysis. Central force motions. Two body Collisions scattering in laboratory and Centre of mass frames. Rigid body dynamics-moment of inertia tensor. Non-Inertial frames and pseudoforces. Variational principle. Generalized coordinates. Lagrangian and Hamiltonian formalism and equations of motion. Conservation laws and cyclic coordinates. Periodic motion: small oscillations, normal modes. Special theory of relativity-Lorentz transformations, relativistic kinematics and mass-energy equivalence.</p> <p>III. Electromagnetic Theory</p> <p>Electrostatics: Gauss's law and its applications. Laplace and Poisson equations, boundary value problems. Magnetostatics: Biot-Savart law. Ampere's theorem. Electromagnetic induction. Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces. Scalar and vector potentials, gauge invariance. Electromagnetic waves in free space. Dielectrics and conductors. Reflection and refraction, polarization, Fresnel's law, interference, coherence, and diffraction, Dynamics of charged particles in static and uniform electromagnetic fields.</p> <p>IV. Quantum Mechanics</p> <p>Wave-particle duality. Schrödinger equation (time-</p>	<p>PHYSICAL SCIENCES Part B (Core)</p> <p>1. Mathematical Methods of Physics</p> <p>Dimensional analysis. Vector algebra and vector calculus. Linear algebra, matrices, Cayley-Hamilton Theorem. Eigenvalues and eigenvectors. Linear ordinary differential equations of first and second order. Fourier series, Fourier and Laplace transforms. Elements of complex analysis, analytic functions. Structure of singularities: poles and branch points, essential singularity. Taylor and Laurent series. Residues and evaluation of integrals. Elementary probability theory, random variables, binomial, Poisson and normal distributions. Central limit theorem. Elements of computational techniques: root of functions, interpolation, extrapolation, integration by trapezoid and Simpson's rule, Solution of first order differential equation (eg, using Runge-Kutta method). Finite difference methods.</p> <p>II. Classical Mechanics</p> <p>Newton's laws. Two-body problems. Motion in a central force field. Scattering in laboratory and centre of mass frames, two-body</p>

<p>dependent and time-independent). Eigenvalue problems (particle in a box, harmonic oscillator, etc.). Tunneling through a barrier. Wave-function in coordinate and momentum representations. Commutators and Heisenberg uncertainty principle. Dirac notation for state vectors. Motion in a central potential: orbital angular momentum, angular momentum algebra, spin, addition of angular momenta, Hydrogen atom. Stern-Gerlach experiment. Time-Independent perturbation theory and applications. Variational method. Time dependent perturbation theory and Fermi's golden rule, selection rules. Identical particles, Pauli exclusion principle, spin-statistics connection.</p>	<p>collision. Dynamics of rigid bodies. Moment of inertia tensor. Non-inertial frames and pseudo-forces Principles of least action. Generalized coordinates and velocities. Lagrangian, Euler-Lagrange equations. Legendre transformation, generalized momenta, Hamiltonian, and Hamilton's equations of motion. Conservation laws and cyclic coordinates. Periodic motion, small oscillations. Normal modes. Special theory of relativity: Lorentz transformations, relativistic kinematics and equivalence of mass and energy.</p>
<p>V. Thermodynamic and Statistical Physics</p> <p>Laws of thermodynamics and their consequences. Thermodynamic potentials, Maxwell relations, chemical potential, phase equilibria. Phase space, micro- and macro-states. Micro-canonical, canonical and grand-canonical ensembles and partition functions. Free energy and its connection with thermodynamic quantities. Classical and quantum statistics. Ideal Bose and Fermi gases. Principle of detailed balance. Blackbody radiation and Planck's distribution law.</p>	<p>III. Electromagnetic Theory Electrostatics: Gauss' law and its applications, Laplace and Poisson equations, boundary value problems. Magnetostatics: Biot-Savart law, Ampère's theorem. Electromagnetic induction. Maxwell's equations in free space and in linear isotropic media, boundary conditions on the fields at interfaces of media. Scalar and vector potentials, gauge invariance, gauge fixing. Electromagnetic waves in free space. Polarization. Dielectrics and conductors. Re-flection</p>
<p>VI. Electronics and Experimental Methods:</p> <p>Semiconductor devices (diodes, junctions, transistors, field effect devices, homo- and hetero-junction devices), device structure, device characteristics, frequency dependence and applications. Opto-electronic devices (solar cells, photo-detectors. LEDs). Operational amplifiers and their applications. Digital techniques and applications (registers, counters, comparators and similar circuits). A/D and D/A converters. Microprocessor and microcontroller basics.</p> <p>Data Interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Least squares fitting.</p> <p><u>PART "B "</u> <u>ADVANCED</u></p>	
<p>I. Mathematical Methods of Physics</p> <p>Green's function. Partial differential equations</p>	

<p>(Laplace, wave and heat equations in two and three dimensions). Elements of computational techniques root of functions, interpolation, extrapolation, Integration by trapezoid and Simpson's rule. Solution of first order differential equation using Runge-Kutta method. Finite difference methods. Tensors. Introductory group theory: $SU(2)$, $O(3)$.</p>	<p>and refraction of electromagnetic waves, total internal reflection. Interference, coherence, and diffraction of electromagnetic waves. Young's double slit experiment.</p>
<p>II. Classical Mechanics</p>	<p>Dynamics of charged particles in static and uniform electromagnetic fields.</p>
<p>Dynamical systems, Phase space dynamick stability analysis, Poisson brackets and canonical transformations. Symmetry, invariance and Noether's theorem. Hamilton-Jacobi theory.</p>	<p>IV. Quantum Mechanics Planck hypothesis. Photoelectric effect. Bohr-Sommerfeld quantization. De Broglie's matter wave.</p>
<p>III. Electromagnetic Theory</p>	<p>Time evolution of a quantum system, Schrödinger equation, unitary evolution operator.</p>
<p>Dispersion relations in plasma. Lorentz invariance of Maxwell's equation. Transmission lines and wave guides. Radiation-from moving charges and dipoles and retarded potentials.</p>	<p>Eigenvalue problem (time-independent Schrödinger equation), examples in one, two and three dimensions, bound states (particle in a box, simple harmonic oscillator, etc.).</p>
<p>IV. Quantum Mechanics: Spin-orbit coupling, fine structure. WKB approximation. Elementary theory of scattering: phase shifts, partial waves, Born approximation. Relativistic quantum mechanics: Klein-Gordon and Dirac equations. Semi-classical theory of radiation.</p>	<p>Wavefunctions and their coordinate and momentum representations. Reflection and transmission in one dimension. Tunnelling through a barrier. Schrodinger and Heisenberg pictures. Equal time commutators of operators, Heisenberg uncertainty relations. Dirac notation for state vectors and operators.</p>
<p>V. Thermodynamic and Statistical Physics</p>	<p>Orbital angular momentum. Angular momentum algebra and its representation. Spin, Stern-Gerlach experiment. Addition of</p>
<p>First- and second-order phase transitions. Diamagnetism, paramagnetism, and ferromagnetism. Ising model. Bose-Einstein condensation. Diffusion equation. Random walk and Brownian motion. Introduction to nonequilibrium processes.</p>	<p>Schrodinger and Heisenberg pictures. Equal time commutators of operators, Heisenberg uncertainty relations. Dirac notation for state vectors and operators.</p>
<p>VI. Electronics and Experimental Methods</p>	<p>Orbital angular momentum. Angular momentum algebra and its representation. Spin, Stern-Gerlach experiment. Addition of</p>
<p>Linear and nonlinear curve fitting, chi-square test. Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors). Measurement and control. Signal conditioning and recovery. Impedance matching, amplification (Op-amp based, instrumentation amp, feedback), filtering and noise reduction, shielding and grounding. Fourier transforms, lock-in detector, box-car integrator, modulation techniques.</p>	<p>of operators, Heisenberg uncertainty relations. Dirac notation for state vectors and operators. Orbital angular momentum. Angular momentum algebra and its representation. Spin, Stern-Gerlach experiment. Addition of</p>

<p>High frequency devices (including generators and detectors).</p>	<p>angular momenta, Clebsch-Gordon coefficients. Wigner-Eckart theorem</p>
<p>VII. Atomic & Molecular Physics</p>	<p>Motion in a central potential, bound states of the hydrogen atom.</p>
<p>Quantum states of an electron in an atom. Electron spin. Spectrum of helium and alkali atom. Relativistic corrections for energy levels of hydrogen atom, hyperfine structure and isotopic shift, width of spectrum lines, LS & JJ couplings. Zeeman, Paschen-Bach & Stark effects. Electron spin resonance. Nuclear magnetic resonance, chemical shift. Frank-Condon principle. Born-Oppenheimer approximation. Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Lasers: spontaneous and stimulated emission, Einstein A & B coefficients. Optical pumping, population inversion, rate equation. Modes of resonators and coherence length.</p>	<p>Identical particles, bosons and fermions. Pauli exclusion principle.</p>
<p>VIII. Condensed Matter Physics</p>	<p>V. Thermodynamic and Statistical Physics</p>
<p>Bravais lattices. Reciprocal lattice. Diffraction and the structure factor. Bonding of solids. Elastic properties, phonons, lattice specific heat. Free electron theory and electronic specific heat. Response and relaxation phenomena. Drude model of electrical and thermal conductivity. Hall effect and thermoelectric power. Electron motion in a periodic potential, band theory of solids: metals, insulators and semiconductors. Superconductivity: type-I and type-II superconductors. Josephson junctions. Superfluidity. Defects and dislocations. Ordered phases of matter: translational and orientational order. kinds of liquid crystalline order. Quasi crystals.</p>	<p>Laws of thermodynamics and their applications (ideal gas, magnetic systems, dielectric materials etc.. Extensive and intensive variables. Thermodynamic potentials, Maxwell relations, chemical potential and phase equilibria. Phase space, micro- and macro-states. Liouville's theorem. Ensembles: microcanonical, canonical and grand canonical ensembles. Partition functions, free energies and their connection with thermodynamic quantities. Probability distributions (binomial, Poisson, Gaussian). Random walk. central limit theorem. Statistical mechanics of discrete (e.g., Ising) and continuous (eg., ideal gas) systems. Classical statistics, Maxwell-Boltzmann distributions</p>
<p>IX. Nuclear and Particle Physics</p>	<p>Quantum statistics, Bose and Fermi systems. Debye theory of specific heat. Black-body radiation and Planck's distribution law. Simple metals.</p>
<p>Basic nuclear properties: size, shape and charge distribution, spin and parity. Binding energy, semi-empirical mass formula, liquid drop model. Nature of the nuclear force, form of nucleon-nucleon potential, charge-independence and charge-symmetry of nuclear forces. Deuteron problem. Evidence of shell structure, single-particle shell model, its validity and limitations. Rotational spectra. Elementary ideas of alpha, beta and gamma decays and their selection rules. Fission</p>	

and fusion. Nuclear reactions. reaction mechanism, compound nuclei and direct reactions.

Classification of fundamental forces. Elementary particles and their quantum numbers (charge, spin, parity, Isospin, strangeness, etc.). Gellmann-Nishijima formula. Quark model, baryons and mesons. C. P. and T Invariance. Application of symmetry arguments to particle reactions. Parity non-conservation in weak Interaction. Relativistic kinematics.

VI. Electronics and Experimental Methods

Semiconductor devices (diodes, junctions, transistors, field effect devices, homo- and hetero-junction devices), device structure, device characteristics and frequency dependence. Opto-electronic devices (solar cells, photo-detectors, LED). Applications of devices. Operational amplifiers and their applications. Digital techniques and their applications (registers, counters, comparators and similar circuits). A/D and D/A converters. Microprocessors and microcontroller basics. Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors). Interpretation and analysis of data. Precision and accuracy. Error analysis, propagation of errors. Curve fitting by least square method. Chi-square test.

Part C (Advanced)

1. Mathematical Methods of Physics

The following are in addition to all the topics in Part B.)

Green's function.

Partial differential equations: Laplace, wave and heat equations in two and three dimensions

special functions
(Hermite, Bessel,
Legendre and Laguerre
functions).

Tensors.

Elements of group theory,
finite groups. Continuous
groups: $SO(3)$ and $SU(2)$.

II. Classical Mechanics

(The following are in
addition to all the topics
in Part B.)

Dynamical systems,
Phase space dynamics,
stability analysis.

Poisson brackets and
canonical
transformations.

Symmetry, invariance
and Noether's theorem.

Hamilton-Jacobi theory.

III. Electromagnetic Theory

The following are in
addition to all the topics
in Part B.)

Dispersion relations in
plasma.

Lorentz covariance of
Maxwell's equation.

Transmission lines and
wave guides.

Radiation from moving
charges and dipoles,
retarded potentials.

IV. Quantum Mechanics

(The following are in
addition to all the topics
in Part B.)

Time-independent
perturbation theory and
applications. Variational
method. WKB
approximation.

Time dependent
perturbation theory:
interaction picture,
constant and harmonic
perturbations, Fermi's

golden rules, selection rules. Sudden and adiabatic approximations.

Scattering in three dimensions: Born approximation, partial waves, phase shifts.

Mixed states, density matrix.

Relativistic quantum mechanics: Klein-Gordon and Dirac equations.

V. Thermodynamic and Statistical Physics (The following are in addition to all the topics in Part B.)

Thermodynamics of first and second order phase transitions. Metastable states, co existence of phases. Landau theory. Spontaneous symmetry breaking. Critical phenomena at second order phase transitions, critical exponents

Phenomenology of dia, para, and ferro- and anti-ferromagnetism. Ising model.

Bose-Einstein condensation.

Superfluidity and superconductivity.

Diffusion equation.

Brownian motion.

Linear response theory.

VI. Electronics and Experimental Methods

(The following are in addition to all the topics in Part B.)

Measurement and control.

Signal conditioning and recovery. Impedance matching, amplification

(op-amp based, instrumentation amp,

feedback), oscillators, filtering and noise reduction, shielding and grounding.

Fourier transforms, lock-in detector, box-car integrator, modulation techniques.

Low temperature measurement techniques.

High frequency devices (including generators and detectors).

VII. Atomic and Molecular Physics

Quantum states of an electron in an atom. Effects due to the spin of electrons. Hund's rule. Spectrum of helium and alkali atom. Periodic table, physical and chemical properties of atoms.

Relativistic corrections and fine structure of hydrogenic atoms.

Hyperfine structure and isotopic shift. LS and JJ couplings. Term symbols. Zeeman, Paschen-Bach and Stark effects.

Electron spin resonance.

Nuclear magnetic resonance, chemical shift.

Hydrogen molecular ion and hydrogen molecule,

Molecular orbitals. Born-Oppenheimer approximation. Bonds.

Electronic, rotational, vibrational and Raman spectra of (diatomic) molecules, selection rules. Frank-Condon principle. Spectral broadening and line width.

Atoms in an electromagnetic field.

Absorption, spontaneous

and stimulated emissions
Einstein A and B
coefficients. Lasers:
optical pumping,
population inversion, rate
equation. Atom cooling
and trapping.

VIII. Condensed Matter Physics

Bravais lattice and
classification of Bravais
lattices in two and three
dimensions. Reciprocal
lattice. Brillouin zone.
Diffraction and structure
factor.

Types of bonding of
solids. Elastic properties.
Phonons, lattice specific
heat.

Free electron theory and
electronic specific heat.

Response and relaxation
phenomena. Drude model
of electrical and thermal
conductivity. Hall effect
and thermoelectric
power.

Electron motion in a
periodic potential, Bloch's
theorem. Band theory of
solids, Fermi surface,
metals, insulators and
semiconductors.

Superconductivity: type-I
and type-II
superconductors. Cooper
pairs. DC and AC
Josephson effect.

Superfluidity.

Translational and
orientational order. Liquid
crystals.

IX. Nuclear and Particle Physics

Properties of nuclei: size,
shape and charge
distribution, spin and
parity. Binding energy.

Semi-empirical mass formula, liquid drop model. Single-particle shell model, magic number. Application to the properties of low lying states, electric quadrupole and magnetic dipole moments. Nature of nuclear force, nucleon-nucleon potential, charge independence and spin dependence of nuclear forces. Deuteron. Collective motion of nuclei: vibration and rotation. Alpha, beta and gamma decays and their selection rules. Parity non-conservation in weak interaction, Wu's experiment. Fission. Nuclear reactions. Fusion, energy generation in the Sun. Accelerators: tandem and linear accelerators, cyclotron and synchrotron. Detectors: bubble and cloud chambers, proportional counters, scintillators, semiconductor based detectors etc. Classification of fundamental forces. Elementary particles and their quantum numbers: charge, spin, parity, isospin, strangeness, etc. Gellmann-Nishijima formula. Quark model, baryons and mesons. Flavour and colour. Constituents of the Standard Model of particle physics: quarks, leptons, gauge bosons

and the Higgs.
Application of symmetry arguments to interaction of particles. P. Cand T invariance.

NOTE: "Part B" of the physics would be consisting of "Numerical Answer Type" (NAT) where the candidates would type in a numerical answer in a box and if it is within bounds set by the paper-setters they get credited. This part shall contain 25 Numerical Answer Type (NAT) questions generally covering the topics given in the Part 'A' (CORE) of syllabus. Each question shall be of 3.5 Marks. The total marks allocated to this section shall be 70 out of 200. Candidates are required to answer any 20 questions. Wrong answers carry no negative marking.