Presidency University
Kolkata

PHYSICS

Curriculum and Syllabus for the

Bachelor of Science (Honours) Degree Programme
Three years: Six semesters;

Courses were approved by the Presidency University Council in July 2013. This curriculum applies to entrants to the UG programmes from 2013 onwards only, starting with the B.Sc. entrants in July 2013.

Structure of UG (Physics Major) Curriculum

Semester	Module	Subject		Credit
1	1	Mathematical Methods 1	PHYS0191	6
	2	Classical Mechanics 1 (including Special Relativity)	PHYS0101	4
2	3	Thermal Physics (Kinetic Theory & Thermodynamics)	PHYS0201	4
	4	Physics Laboratory 1: (Including introduction to Statistics & Error analysis)	PHYS0291	6
3	5	Electromagnetism 1	PHYS0301	4
	6	Optics	PHYS0302	4
	7	Physics Laboratory 2	PHYS0391	6
4	8	A: Mathematical Methods 2 B: Classical Mechanics 2	PHYS0401	4
	9	A: Quantum Physics 1 B: Atomic and Molecular Physics	PHYS0402	4
	10	Physics Laboratory 3	PHYS0491	6
5	11	A: Quantum Physics 2 B: Electromagnetism 2	PHYS0501	4
	12	Electronics	PHYS0502	4
	13	A: Statistical Physics B: Continuum Mechanics	PHYS0503	4
	14	Numerical Methods and Computing	PHYS0591	6
	15	Physics Laboratory 4	PHYS0592	6
6	16	Nuclear & Particle Physics	PHYS0601	4
	17	Solid State Physics	PHYS0602	4
	18	Elective Paper *	PHYS0603	4
	19	Physics Laboratory 5	PHYS0691	6
	20	Supervised Reading or Research project (including Research Skills)	PHYS0692	6

*** Options: Introduction to Astrophysics, Advanced Electronics**

Semester 1

1	Mathematical Methods 1	PHYS0191	6
2	Classical Mechanics 1 (including Special Relativity)	PHYS0101	4

Paper 1
PHYS0191 Mathematical Methods 1 (50 Lectures)

Sequence and series: **[8]**
Sequence and series, convergence, radius of convergence, Taylor's and Maclaurin's series, power series, asymptotic series and divergent series, Cesaro summability, beta and gamma functions.

Linear Differential equations : **[15]**
Equations with constant coefficients - Mechanical and electrical systems, linear operators, general solutions, the Wronskian, complex solutions, free & damped oscillations. Nonhomogeneous equations, forced oscillations and resonance.
Equations with variable coefficients - series solutions, Legendre's and Bessel's equation, orthogonality, generating functions, recurrence relations etc.

Linear vector spaces and matrices: **[8]**
Linear vector spaces, basis for a space, basis transformation, linear transformations, dual space, representations of transformations by matrices, diagonalisation of matrices. Norm and inner products.

Functions of several variables: **[7]**
Differentiable functions – limits and continuity, partial derivatives, total differentials, differentiations of composite functions, chain rule, differentiations of implicit functions, change of variables. Taylor's formula for functions of several variables, critical points of functions of several variables, constrained maxima and minima. Lagrange multipliers. Integral with several variables – double and triple integrals, change of variables in double and triple integrals. Surface integral, line integrals in the plane, line integral independent of path. Green's theorem in the plane. The calculus of variation.

Vector algebra and calculus: **[12]**
Vector triple products. Scalars and vector fields. Continuity of scalars and vector functions. Gradient. Line integral in three dimensional space, line integrals of gradients, independence of path. Regions and their boundaries. Divergence and the divergence theorem. Curl of a vector field, Stokes' formula. Solenoidal and irrotational fields, Line integral in space. Conservative fields, Curvilinear coordinates. Gradient, divergence and curl in orthogonal curvilinear coordinates, non-orthogonal coordinates, co- and contravariant components of a vector.

Paper 2
PHYS0101 Classical Mechanics 1 (including Special Relativity, 50 Lectures)

Classical Mechanics (30 lectures)

Mechanics of a single particle **[6]**
Kinematics – velocity and acceleration in plane polar coordinates, Inertial frame of reference, Newton's laws, Analytical solutions of the dynamical equation in various cases, Conservative forces and concept of potential, Linear momentum.

Mechanics of a system of particles **[5]**
Centre of mass decomposition, Angular momentum and energy, Conservation principles, Two-body system, Collision problems.

Rotational motion **[12]**
Torque, energy and angular momentum of rotating rigid bodies, Moment of inertia – calculation for simple symmetric bodies, Ellipsoid of inertia and inertia tensor, Principal axes, Euler's equation and its solution for symmetric rigid bodies, Non-inertial frames of reference, Coriolis and centrifugal forces, Foucault's pendulum.

Central force **[7]**
Motion under a central force, Orbit equation – detailed discussion for the case of inverse-squared force field, Stability of orbits, Kepler's laws of planetary motion.

Special Relativity (20 lectures)

Kinematics **[8]**
Galilean covariance of Newton's laws, Inconsistency with electromagnetic theory, Interpretation of null results of Michelson-Morley experiment, Postulates of special relativity, Minkowski space-time diagram, Lorentz transformation – simultaneity, spatial contraction, time dilation, Transformation of velocities and acceleration.

Dynamics **[12]**
Four vector – time-like, space-like and light-like, Boost and rotation, Four velocity, Four momentum, Force, Relativistic invariants and dynamics – simple applications to particle decay and elastic collision, Aberration, Doppler effect.

Semester 2

3	Thermal Physics (Kinetic Theory & Thermodynamics)	PHYS0201	4
4	Physics Laboratory 1: (Including introduction to Statistics & Error analysis)	PHYS0291	6

Paper 3
PHYS0201 Thermal Physics (Kinetic Theory & Thermodynamics, 50 Lectures)

Kinetic Theory (20 Lectures)

Kinetic theory of ideal gases **[10]**
Basic postulates, Pressure of an ideal gas, Maxwell's distribution law- mean, root mean square and most probable velocities, Concept of free path and distribution of free paths, Mean free path from Maxwell's distribution, Degrees of freedom, Equipartition of energy and its applications, Transport phenomena - viscosity, thermal conduction and diffusion.

Kinetic Theory of real gases **[5]**
Nature of intermolecular interaction, Experimental isothermal curves of real gases, Virial coefficients, Critical constants, Boyle temperature, Van der Waals equation of state, Law of corresponding states, Survey of other equations of state for real gases.

Brownian motion **[5]**
Perrin's experiment, Random walk, Fluctuation – Dissipation theorem, Langevin theory of translational Brownian motion, Einstein-Smoluchwoski theory.

Thermodynamics (30 Lectures)

Basic Concepts **[4]**
Microscopic and macroscopic points of view : thermodynamic variables of a system, State function, exact and inexact differentials, Extensive and intensive variables, Thermal equilibrium, Zeroth law of and concept of temperature. Equation of state.

First Law of Thermodynamics **[7]**
Equilibrium of a thermodynamic system, internal energy, external work, first law of thermodynamics and applications including magnetic systems, specific heats and their ratio, isothermal and adiabatic changes in perfect and real
gases.

Second Law of Thermodynamics **[8]**
Reversible and irreversible processes, indicator diagram,
Carnot's engine and its efficiency, Carnot's theorem.Principle of operation of refrigerator, Kelvin's scale of temperature, relation toperfect gas scale, second law of

thermodynamics – different formulations and their equivalence, Clausius inequality, entropy, change of entropy in simple reversible and irreversible processes, Entropy of ideal gas,

Entropy and disorder **[3]**
Randomness and entropy, Entropy and information, equilibrium and entropy principle, degradation of energy. Third law of thermodynamics.

Thermodynamic Functions **[4]**
Enthalpy, Helmholtz and Gibbs' free energies; Legendre transformations, Maxwell's relations and simple deductions using these relations; thermodynamic equilibrium and free energies.

Change of State **[4]**
Equilibrium between phases, triple point : Gibbs' phase rule (statement only) and simple applications.Phase transitions and its order, Ehrenfest criterion. Clausius-Clapeyron's equation. Joule-Thomson effect. Adiabatic demagnetisation.

Paper 4
PHYS0291 Physics Laboratory 1

Lectures: (16 lectures)

1. Data acquisition
2. Data interpretation:
    a. Dimensional analysis and significant figures
    b. Basic statistical distributions: Normal distribution
    c. Error analysis: random and systematic error. Percentage error.
    d. Regression. Model fitting. Chi-Square distribution and significance of fits.
    e. Histograms. Kolmogorov-Smirnoff test and the comparison of two distributions.

Laboratory Experiments

1. Torsion Experiment and determination of rigidity modulus
2. Determination of Young's modulus of the material of a metallic bar by bending of a beam
3. Determination of thermoelectric power using thermocouples
4. Determination of thermal conductivity of bad conductor by Lee-Chorlton method
5. Study of Network theorems (Thevenin, Norton and Maximum power transfer)
6. Determination of Planck's constant by Photoelectric method

Semester 3

5	Electromagnetism 1	PHYS0301	4
6	Optics	PHYS0302	4
7	Physics Laboratory 2	PHYS0391	6

Paper 5
PHYS0301 Electromagnetism 1 (Electrostatics & Magnetostatics, 50 Lectures)

Electrostatics (25 lectures)

Field, Potential, Gauss' Law **[8]**

Coulomb's law, Superposition principle, Intensity & potential. Potential and field due to different charge distribution. Gauss law and its application. Earnshaw's theorem.

Multipole Expansion **[4]**

Potential.and field due to a dipole, Force & torque on a dipole in an external field. Dipole-dipole interaction, Multipole Expansion for bounded charge distribution.

Dielectrics **[6]**

Polarization and charge density. Molecular polarizablility. Electric displacement vector. Electric field in cavities of dielectrics. Electrostatic energy.

Laplace equation & Electrical Images **[7]**

Possion and Laplace equation, Boundary conditions, Uniqueness Theorem. Boundary value problems with the help of Electrical images.

Magnetostatics (25 Lectures)

Magnetic effect of steady current, Vector Potential **[12]**

Equation of continuity and steady current. Lorentz force and concept of magnetic induction; force on linear current element; Biot-Savart's law, Ampere's circuital law. Magnetic vector potential; calculation of vector potential and magnetic induction in simple cases. Vector potential due to closed current loop - magnetic dipole term; Field due to a dipole; Concept of magnetic shell; Magnetic dipole moment for rotating charge bodies, Gyro-magnetic ratio, Force & torque on a magnetic dipole.

Field and magnetic materials **[7]**

Free current and bound current; surface and volume density of current distribution; magnetisation; non-uniform magnetisation of matter; Introduction of **H**; Magnetostatic boundary conditions. Magnetic scalar potential; Field due to uniformly magnetized sphere. Hysteresis and iron loss.

Electromagnetic Induction **[6]**
Faraday's and Lenz's law. Motional e.m.f.-simple problems. Calculation of self and mutual inductance in simple cases. Energy stored in magnetic field. Energy of a magnetic dipole.

Paper 6
PHYS0302 Optics (50 Lectures)

Geometrical optics (12 Lectures)

Fermat's principle and its application to plane and curved surfaces, Matrix method in paraxial optics and its applications, Seidel and chromatic aberrations – elementary discussions.

Physical optics (38 Lectures)

Waves **[4]**
Superposition of waves, Huygens' Principle.

Interference of Light **[12]**
Young's experiment, coherence, Interference by division of wavefront and division of amplitude. Multiple beam interference, Interferometers.

Diffraction of Light **[12]**
Fresnel and Fraunhofer diffraction, Huygens-Fresnel theory, Zone plate, Different apertures, Fraunhofer diffraction due to a single slit, double slit, transmission grating, Resolving power of optical systems.

Polarization of Light **[10]**
Unpolarized and partially polarized light, State of polarization, Polarization by reflection and scattering, Brewster's angle. Polaroid and Malus' law. Optical anisotropy, Wave equation in anisotropic media, birefringence, *o*- and *e*-rays, double refraction, Polarizing beamsplitters and waveplates.

Paper 7
PHYS0391 Physics Laboratory 2

The contents for this laboratory will be submitted for Council approval at a later date.

Semester 4

8	A: Mathematical Methods 2 B: Classical Mechanics 2	PHYS0401	4
9	Quantum Physics 1	PHYS0402	4
10	Physics Laboratory 3	PHYS0491	6

Paper 8
PHYS0401 (Mathematics Methods 2 & Classical Mechanics 2, 50 Lectures)

Mathematical Methods 2 (25 Lectures)

Fourier Series & Fourier Transforms [10]
Fourier series as eigen function expansions, sine and cosine series. Complex Fourier series and the Dirac δ function. Fourier Transform and Partial Differential Equation – the case of a diffusion equation.

Partial Differential Equation [15]
Classification of PDEs. Some examples of PDEs. Solution of PDEs with separation of variables and eigenfunctions. Boundary and initial conditions – vibration of a string. Laplace's equation and its solution in Cartesian, spherical polar with axially symmetric coordinate system and cylindrical polar with infinite cylinder coordinate system. Solution of 1- D and 2 – D wave equations. Solution of heat conduction equation in 1-D.

Classical Mechanics 2 (25 Lectures)

Lagrangian formulation [12]
Generalised coordinates, Constraints and degrees of freedom, D' Alembert's principle, Lagrange's equations of motion for conservative holonomic systems, Generalised momentum, Cyclic coordinates, Symmetries and conservation principle, Application to simple cases, Lagrangian of oscillating systems, Secular equation for small oscillations and its solution, Normal coordinates and modes.

Hamiltonian formulation [7]
Construction of Hamiltonian using Legendre transformation, Hamilton's equations of motion and its application to simple cases, Hamiltonian for a relativistic particle.

Canonical transformation [6]
Canonical transformation, Poisson brackets.

Paper 9
PHYS0402 (Quantum Physics 1 & Atomic and Molecular Physics, 50 Lectures)

Quantum Mechanics 1 (25 Lectures)

Historical Development **[5]**
Black body radiation, Planck's formula, de Broglie hypothesis, Compton effect, Electron double-slit experiment, Davisson-Germer experiment, Heisenberg's uncertainty principle.

Basics of Wave Mechanics **[10]**
Concept of wave function, Wave packets, Group and phase velocities, Principle of superposition, Schrodinger equation, Probabilistic interpretation of the wave function, Properties of the solution of Schrodinger equation, Stationary states.

Operator Formulation **[10]**
Dynamical variables as linear harmonic operators, Momentum, energy and angular momentum operators, Eigenvalue equation, Measurement of observables, Expectation values, Ehrenfest's Theorem, Commutation relation between operators and simultaneous measurements, Solution of eigenvalue problem for a free particle and for motion of a particle in an infinite square well potential.

Atomic and Molecular Physics (25 Lectures)

Atomic Spectra **[5]**
Spectrum of light, Bohr model for hydrogen like ions, experimental evidences, Rydberg atoms, Franck-Hertz experiment and its improvements, Bohr-Sommerfeld quantization, spectra of alkali atoms.

Vector Atom Model **[8]**
Magnetic moment of an electron for orbital motion, space quantization, Stern-Gerlach experiment, electron spin, vector model, Lande g factor, interpretation of Stern-Gerlach experiment, doublet lines of alkali spectra, spin-orbit interaction, Zeeman effect (normal & anomalous), Paschen-Back effect.

Many Electron Atoms **[4]**
Helium spectra, LS and JJ coupling, Pauli exclusion principle, Hund’s rules, equivalent and non-equivalent electrons.

Molecular spectra **[5]**
Diatomic molecules-rotational and vibrational levels, basic ideas about molecular spectra, Raman Spectra.

Laser Physics **[3]**
Population inversion, Einstein’s A, B coefficients, feedback of energy in a resonator, three level and four level systems.

Paper 10
PHYS0491 Physics Laboratory 3

The contents for this laboratory will be submitted for Council approval at a later date.

Semester 5

11	A: Quantum Physics 2 B: Electromagnetism 2	PHYS0501	4
12	Electronics	PHYS0502	4
13	A: Statistical Physics B: Continuum Mechanics	PHYS0503	4
14	Numerical Methods and Computing	PHYS0591	6
15	Physics Laboratory 4	PHYS0592	6

Paper 11
PHYS0501 (Quantum Physics 2 & Electromagnetism 2, 50 Lectures)

Quantum Physics 2 (25 Lectures)

Simple applications **[8]**
Solution of eigenvalue problem for the cases of finite well potential, delta function potential, potential step and rectangular potential barrier

Linear harmonic oscillator **[4]**
Solution of Schrodinger equation, Quantisation by operator method.

Hydrogen atom problem **[10]**
Central force problem, Reduction to 1 dimension, Angular momentum – eigenvalues and eigenfunctions, Concept of spin, Technique for adding spin for two spin-1/2 case, Bound states of hydrogen atom, Scattering states.

Symmetry and conservation principle **[3]**
Energy, Linear and Angular momentum, Parity

Electromagnetism 2 (25 Lectures)

Maxwell's Equations & Electromagnetic Waves **[10]**
Displacement Current, Maxwell's Equations in vacuum in presence of source charges and currents, plane wave solutions, energy & momentum relations in electromagnetic field - Poynting's theorem, Scalar & vector potentials, gauge transformation, Maxwell's

Equations in linear isotropic media, Wave equation, transverse nature, boundary conditions. Wave equation in conducting medium.

Reflection and refraction at plane boundary **[9]**

Reflection and transmission coefficients, Fresnel's formula, change of phase on reflection, polarization on reflection and Brewster's law, total internal reflection. Reflection and transmission at metallic surface –skin effect and skin depth, propagation of E-M waves between parallel and conducting plates – wave guides (rectangular only).

Dispersion & Scattering **[6]**

Equation of motion of an electron in a radiation field : Lorentz theory of dispersion – normal and anomalous; Sellmeier's and Cauchy's formulae, absorptive and dispersive mode, half power frequency, band width. Scattering of radiation by a bound charge. Rayleigh's scattering & blueness of the sky.

Paper 12
PHYS0502 Electronics (50 Lectures)

Semiconductors **[16]**

Semiconductor materials, doping, *n* and *p*-type semiconductors, energy band and Fermi level, *p*-*n* junction diode: construction, current-voltage characteristics at forward and reverse bias, junction capacitance, avalanche and Zener breakdown, voltage regulation property of Zener diode, simple diode circuits: half-wave, full-wave and bridge rectifiers, filters, diode clipper and clamper, brief idea of different types of diodes based on *p*-*n* junction. Bipolar junction transistor (BJT) : construction, current amplification mechanism, common-base configuration and α, common-emitter configuration and β, common-collector configuration and emitter follower, hybrid parameters, BJT biasing, stability, load line and Q-point, transistor as voltage amplifier, statement of Thevenin's theorem, Norton's theorem, superposition theorem and maximum power transfer theorem and use of those in course of transistor circuit analysis, Field effect transistors: construction and characteristics of JFET and MOSFET, mutual conductance, drain resistance and amplification factor, enhancement and depletion type MOSFETs, common-source, common-drain and common-gate amplifiers, brief introduction to light-emitting diode, photodiode and solar cell.

Amplifiers and Oscillators **[8]**

Principle of feedback, positive and negative feedback, advantages of negative feedback, transistor power amplifier, tuned and wideband amplifier, class A, class B and class C amplifiers, push-pull amplifier, multistage amplifier, types of coupling.
Barkhausen criterion for sustained oscillation, Hartley and Colpitts oscillators, Wien bridge oscillator, crystal oscillator, multivibrator.

Operational Amplifier **[10]**

Properties of ideal operational amplifier, differential amplifier, common mode rejection ratio, inverting amplifier (voltage shunt feedback) and noninverting amplifier (voltage series feedback), voltage follower, circuits performing mathematical operations, such as adder, subtractor, multiplier, integrator and differentiator, comparator, Schmitt trigger, precision rectifier, active filter.

Digital electronics **[10]**

Decimal, binary and hexadecimal numbers, Boolean algebra, logic gates and universal gate, De Morgan's theorems, Boolean simplifications, sum-of-product and product-of-sum form, Karnaugh map, Logic families, Combinational logic circuits: adder, comparator, multiplexer, demultiplexer, sequential logic circuits: flip-flops – RS, D, JK and JK master-slave, use of clock pulse, shift register, counters, digital-to-analog and analog-to-digital converters.

Principles of Communication **[6]**

Need for modulation, amplitude modulation (AM), frequency modulation (FM) and phase modulation (PM), demodulation of AM wave (diode detector), FM wave (slope detector) and related circuits, Types of noise, equivalent noise voltage, noise current, noise power and noise resistance, propagation of electromagnetic waves through the atmosphere, ionosphere and its influence on radiowaves, optical fibre and communication through optical fibre.

Paper 13
PHYSICS0503 (Statistical Physics & Continuum Mechanics, 50 Lectures)

Statistical Physics (25 Lectures)

Statistical description of thermodynamic systems **[5]**

Limitations of thermodynamics. Statistical description of a system, Microstates & Macrostates, Phase space, Ergodicity, Concepts of statistical equilibrium, Liouville's Theorem. Isolated system, Postulate of equal a priori probability. Statistical definitions of temperature and entropy.

Statistical ensembles and applications of classical statistics **[12]**

Interacting systems, Thermal equilibrium and canonical ensembles, Gibbs distribution, Partition function as a generating function of all thermodynamic quantities. Simple applications of Gibbs distribution, Partition function and density of states, Grand canonical ensemble and chemical equilibrium, Grand partition function and simple applications, Fluctuations and its role in statistical mechanics, Equivalence of ensembles. Equipartition of energy, examples. Applications of Gibbs distribution in noninteracting spin systems. Ideal gas, equation of state, energy, specific heat. MaxwellBoltzmann distribution. Entropy of ideal gas. Gibbs paradox. Applicability criteria of classical statistics.

Developments & Applications of Quantum Statistical mechanics **[8]**
Spin dependent Quantum states of system of particles, FermiDirac statistics, Fermi energy, average energy at T=0. Electronic specific heat at nonzero finite (low) temperature. Simple applications in Pauli spin paramagnetism, electrical conductivity, thermoionic emission. BoseEinstein statistics, Simple applications in Black body radiation, BoseEinstein condensation.

Continuum Mechanics (25 Lectures)

Elasticity **[10]**
Stress and Strain tensors, Hooke's law, Isotropic solids and their conditions for equilibrium, Energy of deformation, Propagation of waves in an elastic medium.

Fluid Mechanics **[15]**
The equation of continuity, Euler's equation for ideal fluids, Hydrostatics, Bernoulli's theorem, Potential flow, Incompressible fluids, Newtonian fluids, Navier-Stokes equation and its applications. Poiseuille's formula, Couette flow, Turbulent flow and Reynold's number, Brief introduction to astrophysical fluid dynamics.

Paper 14
PHYS0591 Numerical Analysis and Computing

1. Computer Language (one of FORTRAN/C/C++/Python)

Concept of algorithm, Basic syntaxes of constant, variables. elementary operations. Arithmetic expressions, Logical expressions, Recursion, array variables, Basic I/O statements, function subprogram and subroutines. Graphics.

2. Numerical analysis (assigned problems as Laboratory experiments)

Group A
(i) Sorting of data
(ii) Statistical analysis (mean, median, mode)
(iii) Distribution of prime numbers
(iv) Sum of different types of series term by term with a specified accuracy
(v) Products of two vectors
(vi)Matrix operations (addition, subtraction, multiplication,transpose)

Group B
(i) Solution of simultaneous linear equations by Gauss-Siedel method
(ii) Finding real roots by Bisection and Newton-Raphson method
(iii) Calculations of derivatives by forward difference and central difference method.
(iv) Integration by trapezoidal and Simpson's rule.
(v) Integration by statistical method.
(vi) Solving ODE by Euler method.

Paper 15
PHYS0592 Physics Laboratory 4
The contents for this laboratory will be submitted for Council approval at a later date.

Semester 6

16	Nuclear & Particle Physics	PHYS0601	4
17	Solid State Physics	PHYS0602	4
18	Elective Paper (Astrophysics, Advanced Electronics)	PHYS0603	4
19	Physics Laboratory 5	PHYS0691	6
20	Supervised Reading or Research project (including Research Skills)	PHYS0692	6

Paper 16
PHYS0601 (Nuclear and Particle Physics, 50 Lectures)

Nuclear structure and properties **[7]**
Properties of nuclei - size, shape, charge distribution, binding energy, spin, electric and magnetic moment, parity, Force between nucleons – charge independence, Nuclear stability – liquid drop model and semi-empirical mass formula, Extreme single particle shell model (qualitative), Magic numbers.

Unstable nuclei **[12]**
Rutherford scattering, Alpha decay – Geiger-Nuttal law, straggling, Beta decay – Kurie plot, neutrino hypothesis, energy levels and decay schemes, selection rules, Gamma decay spectra, isomeric states, energy levels.

Nuclear Reaction **[13]**
Conservation principles, Q value and threshold, Types of nuclear reaction, Direct reaction, Bohr's postulate of compound nucleus formation – Ghoshal's experiment, Fission - spontaneous and induced, energy and mass distribution of fragments, explanation from liquid drop model, chain reactions, nuclear reactors, Fusion – explanation from liquid drop model.

Elementary particle physics **[18]**
Four fundamental interaction, Quantum numbers – mass, charge, spin,isospin, strangeness,parity, hypercharge, Conservation laws, Particle classification – hadron and lepton, Elementary idea about quark model of hadrons – baryon and mesons, Gell-Mann plot, Elementary discussion of key experiments that led to the current understanding of electro-weak and strong interaction.

Paper 17
PHYS0602 Solid State Physics (50 Lectures)

Crystal Structure of Solids **[8]**

Crystalline periodicity, crystal symmetry, Bravais lattices, position, directions and planes in crystals. Simple lattice, Close-packed structures & Reciprocal lattice. The Bragg diffraction law, Laue condition of X-ray diffraction, determination of crystal structure with X- rays.

Bonding in Solids **[2]**

Different types of bonding – ionic, covalent, metallic, van der Waals & hydrogen type.

Energy band Structure **[9]**

Periodic potential in a crystalline solid, Bloch theorem, Kroning Penny model and the formation of energy allowed and forbidden energy gaps, number of electrons in a band, reciprocal effective mass tensor of electrons. Electrons and holes. Metals, insulators and semiconductors.

Free Electron Theory of Metals **[6]**

Relaxation time, mean free path, mobility and thermal conductivity. Drude model – electrical conductivity. Wiedemann Franz Lorentz relation. Hall effect in metals.

Lattice Vibration & Specific heat of solids: **[7]**

One dimensional monatomic lattice, periodic boundary condition & vibrational modes of the 1- D lattice, Classical calculation of lattice specific heat. Einstein's and Debye's theories of specific heat.

Dielectric Properties of Solids: **[6]**

Static dielectric constant of solids, dipole moment and polarization, types of polarization –electronic, ionic and orientational polarizations. Internal fields of solids. Clausius-Mosotti relation.

Magnetic Properties of Solids: **[12]**

Magnetic susceptibility, Diamagnetism of core electrons. Paramagnetism. Langevin equations for dia & paramagnetism. Curie's law. Quantum theory of paramagnetism (for S=1/2 system). Spontaneous magnetization and ferromagnetic properties of solids. Temperature variation of spontaneous magnetization, Curie-Weiss law. Domain structure & hysteresis in ferromagnets.

Paper 18
PHYS0603 Elective papers (50 Lectures)

Paper 18A
Astrophysics

Introduction to Observational Astronomy **[8]**

Celestial sphere, Coordinate systems, Measurement of time and distance, Luminosity, Apparent and absolute magnitude, Colour index, Measurement of mass, Electromagnetic spectrum, Observational tools for multi-wavelength astronomy.

Introductory Stellar astrophysics **[18]**

Stellar spectra – classification, Saha equation, Hertzsprung-Russell diagram, Stellar structure - hydrostatic equilibrium, Polytropes, Lane Emden equation – analytic solutions, Stellar energy generation - nucleosynthesis, Radiative transfer.

Stellar evolution **[12]**

Fate of massive stars – brown dwarfs, supernovae, Compact objects – white dwarfs, neutron stars and black holes.

Introductory extragalactic Astrophysics **[12]**

Galaxies – classification, Galactic structure, Milky Way galaxy, Normal and active galaxies, Structure of the Universe, Introduction to observational cosmology.

Paper 18B
Advanced Electronics

Amplifiers and Oscillators **[8]**

Voltage and current amplifiers, principle of feedback, positive and negative feedback, advantages of negative feedback, transistor power amplifier, tuned and wideband amplifier, class A, class B and class C amplifiers, push-pull amplifier, multistage amplifier, types of coupling, Barkhausen criterion for sustained oscillation, Hartley and Colpitts oscillators, Wien bridge oscillator, crystal oscillator, multivibrator.

Operational Amplifier **[10]**

Properties of ideal operational amplifier, differential amplifier, common mode rejection ratio, inverting amplifier (voltage shunt feedback) and noninverting amplifier (voltage series feedback), voltage follower, circuits performing mathematical operations, such as adder, subtractor, multiplier, integrator and differentiator, comparator, Schmitt trigger, precision rectifier, active filter.

Digital Electronics **[10]**

Logic families, combinational and sequential logic circuits, multiplexer, demultiplexer, decoder, encoder, diode ROM, flip-flops: RS, D, JK, JK master-slave, use of clock pulse, shift register, counters, digital-to-analog and analog-to-digital converters.

Optoelectronics **[4]**
Use of geometrical and physical optics in electronic devices, optical fibre, core and cladding, step index and graded index fibres, communication through optical fibre, light-emitting diode, photodiode and solar cell.

Instrumentation **[5]**
Cathode ray oscilloscope: construction and measurement of electrical quantities, introduction to microprocessor, block diagram of 8085, types of instructions, op-code, a brief idea on microprocessor programming and interfacing.

Signals and Noise **[5]**
Types of noise, equivalent noise voltage, noise current, noise power and noise resistance, antenna, propagation of electromagnetic waves through the atmosphere, ionosphere and its influence on radiowaves, very brief idea on satellite communication, digital communication and mobile communication.

Semiconductor Science & Technology **[8]**
Introduction to bulk and epitaxial crystal growth, diffusion and ion implantation, brief idea on integrated circuit (IC), lithography, metal-semiconductor contacts, Special semiconductor devices: *p-n-p-n* switch, SCR, diac, triac, tunnel diode, IMPATT diode.

Paper 19
PHYS0691 Physics Laboratory 4

The contents for this laboratory will be submitted for Council approval at a later date.

Paper 20
PHYS0692 (Research Skills & Supervised reading or research project)

This module will consist of two parts. In the first part, basic principles of research skills will consist of lectures on statistical analysis, data interpretation, simulations, scientific ethics and Latex document processing. In the second part, the student will undertake a reading project in a small group, or a small research project under close supervision.

Research skills (16 lectures)

A) Bayesian and Frequentist approaches to Statistics
B) Advanced Statistical Techniques for Data Analysis
C) Latex document processing ,
D) Giving talks: oral presentation
E) Lectures on career development, Scientific ethics etc. (Non-examinable)

The examination will consist of a problem-solving test on A, B and C, and this will constitute marks equivalent to 1 credit. The oral presentation and LateX skills will be tested below.

Supervised reading or research (12 weeks)

The student will be given the choice of a group reading project of a research project. This amounts to 4 credits.

In the reading project, students in small groups (2 or 3) undertake a reading project on a complex topic not covered by the UG programme, under supervision, and individually write a 4,000 word essay or paper (in LateX) on some pre-determined aspect of the topic.

The research project will be supervised by a member of faculty, and students will perform the research in pairs, each working on a similar project but with different goals. Each student will have to submit a 4,000 word report on their research.

For both, an oral presentation will have to be given by each individual and this will constitute marks equivalent to 1 credit.