Department of Physics, Presidency University

Syllabus (w. e. f. July 2017) for 3-Year 6-Semester B. Sc. Degree Programme

Sem	Subject	Paper Code	Category	Credit
1	Mathematical Physics-1	PHYS0101	Theoretical	4
	Newtonian Mechanics	PHYS0191	Lab-based Sessional	6
2	Electromagnetic Theory-1	PHYS0201	Theoretical	4
	Physics Laboratory-1	PHYS0291	Lab-based Sessional	6
3	Mathematical Physics-2	PHYS0301	Theoretical	4
	Electromagnetic Theory-2	PHYS0302	Theoretical	4
	Physics Laboratory-2	PHYS0391	Lab-based Sessional	6
4	Classical Mechanics	PHYS0401	Theoretical	4
	Quantum Theory and Special Relativity	PHYS0402	Theoretical	4
	Physics Laboratory-3	PHYS0491	Lab-based Sessional	6
5	Quantum Mechanics	PHYS0501	Theoretical	4
	Electronics	PHYS0502	Theoretical	4
	Thermal and Statistical Physics	PHYS0503	Theoretical	4
	Physics Laboratory-4 (Numerical Methods and Computing)	PHYS0591	Lab-based Sessional	6
	Physics Laboratory-5	PHYS0592	Lab-based Sessional	6
6	Nuclear and Particle Physics	PHYS0601	Theoretical	4
	Solid State Physics	PHYS0602	Theoretical	4
	Elective Paper *	PHYS0603	Theoretical (Choice Based)	4
	Physics Laboratory-6	PHYS0691	Lab-based Sessional	6
	Supervised Reading/Project	PHYS0692	Choice based Sessional (theoretical or experimental)	6

*Options: Astrophysics and Cosmology, Analog and Digital Electronics, Quantum Optics and Quantum Information (not all electives will be offered every semester)

Semester-1

PHYS0101: Mathematical Physics-1 [50 Lectures]

Vector Algebra, Matrices and Vector Spaces [7]

Fundamental operations: Scalars, vectors and equality, base vectors, Basic operations in vector space, scalar triple product, vector triple product, differentiation of vectors. Cartesian reference frames. Matrices: Functions of matrices transpose of matrices, the complex and Hermitian conjugates of a matrix, inverse of matrix. Special types of square matrix: Diagonal, triangular, symmetric, orthogonal, Hermitian, unitary. Eigenvectors and eigenvalues. Linear transformation, transformation of base vectors and similarity transformations, orthogonal transformation, diagonalisation of matrices.

Functions of Several Variables [12]

Differentiable functions: Limits and continuity, partial derivatives, total differentiations, differentiation of composite functions, chain rules, differentiation of implicit functions, change of variables. Application of differentiations: Taylor's formula for functions of several variables, maxima and minima of functions of several variables, constrained maxima and minima, Lagrangian multipliers. Integrals with several variables: Double integrals, change of variables, change of variables in triple integrals, surface integrals, line integrals in the plane, line integrals independent of the path, Green's theorem in the plane.

Scalar and Vector Fields [7]

Scalar and vector functions, Gradient of a scalar field, line integrals of Gradients, independent of path, regions and their boundaries, Divergence of a vector field, Divergence theorem, Curl of a vector field, Stokes' formula, line integral in space.

Series and Sequences [6]

Infinite Series: Infinite Sequences, summations, infinite series, tests for convergence, operations on series. Sequences and Series of Functions: Properties of uniformly convergent series. Application of Common Series: Power series, Taylor Series, Series for some familiar functions. Integrals and Series as Functions:Integrals as functions, Gamma Function, Beta Function, Error Function.

Linear Differential Equations [18]

Regular and singular points, Equations with constant coefficients: Mechanical and electrical systems, linear operators, general solutions, Wronskian, complex solutions, free & damped oscillations. Non-homogeneous equations, forced oscillations and resonance. Equations with variable coefficients: Series solutions, Legendre's and Bessel's equation, orthogonality, generating functions, recurrence relations etc.

PHYS-0191: Newtonian Mechanics [75 lectures]

Mechanics of a Single Particle [7]

Kinematics, Velocity and acceleration in plane polar coordinates, Inertial frame of reference, Newton's laws, Analytical solutions of the dynamical equation in various cases: Resistive medium, Contact forces.

Mechanics of a System of Particles [7]

Conservation of linear momentum, Centre of mass, Momentum transport: rocket motion, Conservation of energy, Conservative forces and concept of potential.

Rotation [6]

Torque, Rotational energy, Angular momentum, Moment of inertia – calculation for simple symmetric bodies, Collision in two dimension.

Central Force [12]

Properties of motion under central force: Energy, angular momentum, eccentricity, Kepler's laws, Orbit equation: detailed discussion for the case of inverse-squared force field, Newtonian gravity, Effective potential, Stability of orbits, Scattering in laboratory and Centre of mass frames.

Non-inertial Reference Frame [8]

Necessity of pseudo forces, Centrifugal force, Coriolis force, Lateral motion of freely falling particles, Foucault pendulum, Tidal forces.

Measurement Techniques [35]

1. Linear air track I.

Uniform motion, Accelerated motion, Verification of laws of kinematics.

2. Linear air track II.

Collision , Conservation of linear momentum and energy.

3. Determination of rigidity modulus of a material using torsional pendulum.

Measurement of moment of inertia of a cylinder, Time period.

4. Computer interfacing of the simple and torsional pendulum experiments.

Automated detection of motion and measurement of time interval, expEyes kit.

5. Determination of the period of a driven pendulum using resonance.

Change of time period with length of string, Detection of resonance.

6. Propagation and reporting of uncertainties.

Characterisation of uncertainties present in various basic instruments in the lab, Effect of uncertainties in the final result.

7. Classification of experimental uncertainties.

Instrumental, random, and systematic uncertainties in simple and torsional pendulum experiments.

8. Plotting and fitting of acquired data points.

GNUPLOT, Plotting uncertainties with data, Finding the best-fit slope and intercept of acquired data, uncertainties in best-fit parameters.

9. Design of additional experiments with the linear air track

Inclined plane, Frictional coefficient.

Semester-2

PHYS-0201: Electromagnetic Theory-1 [50 Lectures]

Electrostatics [18]

Field, Gauss' Law and curl freedom and their application, Multipole Expansion, Electrostatic energy, Poisson and Laplace equation, Boundary conditions, Uniqueness Theorem, Boundary value problems, Method of image, Dielectrics: Polarisation and charge density, Molecular polarizablility, Electric displacement vector, Electric field in cavities of dielectrics, Capacitors.

Magnetostatics [16]

Magnetic effect of steady current, 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, Magnetic dipole moment for rotating charge bodies, Gyro-magnetic ratio, Force & torque on a magnetic dipole.

Field and magnetic materials [6]

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 magnetised sphere. Hysteresis and iron loss.

Electromagnetic Induction [4]

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.

Maxwell's Equations [6]

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.

PHYS-0291: Physics Lab-1 [75 Sessions]

1. Determination of Young's modulus of the material of a metallic bar by the bending of a beam:

Theory of Bending beam, Measurement and plotting of load vs depression, Regression fitting to get Young's Modulus and its uncertainty

2. Determination of thermoelectric power using thermocouples.

Calibration of potentiometer, Determination of load resistance, measurements and plotting the temperature of the hot junction vs null point, Determination of thermoelectric power

3. Determination of thermal conductivity of bad conductor by Lee-Chorlton method

Measurements of physical parameters for the bad conductor, Obtaining the steady state temperatures, Bedford correction

4. Study of Thevenin theorem.

Thevenin's Theorem, Design the circuit (i.e. Wheatstone bridge), obtain Thevenin's resistance and voltage experimentally and compare that with the theory

5. Study of Norton and Maximum power transfer theorem

Norton's Theorem, Design the circuit (i.e. Wheatstone bridge), obtain Norton′s current experimentally and compare that with the theory

6. Determination of Planck's constant by Photoelectric method and Verify $1/r^2$ law for a point source

Measurements and plotting of stopping potential vs frequency, determination of Planck's constant by regression fitting and its uncertainty, I-V characteristics of material, verify the light intensity proportional to $1/r^2$ for the source

7. Determination of the acceptability of a measured value

Confidence limit, Normal distribution, Chi-square distribution

8. Determination of the importance of averaging large number of data

Concept of different moments:mean, standard deviation, Standard deviation on the mean, 1/sqrt(N) uncertainty

9. Finding best-fit parameters by fitting non-linear curve to measured data

Chi-square statistics, computer program for two parameter non-linear fit of a data and uncertainty

Semester-3

PHYS0301: Mathematical Physics-2 [50 Lectures]

Fourier Series & Fourier Transforms [10]

Fourier series as eigenfunction expansions, sine and cosine series. Complex Fourier series, Parseval's theorem. Generalised Fourier series and the Dirac δ function. Summation of Fourier series. The Gibbs phenomenon. Fourier Transform: Cosine and sine transform, the transform of derivatives, development of formal solution of the differential equation using Fourier transform.

Partial Differential Equation(PDE) [17]

Classification of PDEs. Some examples of PDEs. Solution of PDEs with separation of variables and eigenfunctions. Boundary and initial conditions, Laplace's equation and its solution in Cartesian, Vibration of a string, 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.

Tensor Analysis [12]

Cartesian tensors: first and zero order Cartesian tensors, second and higher order Cartesian tensors. Algebra of tensors: summation, multiplication, contraction, inner product, the quotient quotient law. The tensors isotropic tensors, improper rotation and pseudo-tensors, dual tensors. Non-Cartesian tensors, the metric tensor, General coordinate transformation and tensors, Applications (e.g., Electromagnetic field tensors, Stress-strain tensors, Moment of inertia tensor)

Complex Variables [11]

Complex numbers, functions of a complex variables, elementary complex functions, analytic functions of a complex variables, harmonic functions, Cauchy's integral theorem, Cauchy's integral formula. Taylor's series, Laurent's expansion.

PHYS-0302: Electromagnetic Theory-2 [50 Lectures]

Electromagnetic Waves [14]

Wave equation, Reflection and transmission coefficients, Fresnel's formula, Unpolarized and partially polarized light, State of polarization, Superposition of polarized light. Polarization on reflection and scattering, Brewster's angle. Polaroid and Malus' law. Reflection and transmission at metallic surface – skin effect and skin depth, propagation of E-M waves between parallel and conducting plates – wave guides, Lorentz theory of dispersion.

Light in Anisotropic media [10]

Optical anisotropy, Wave equation in anisotropic media, birefringence, *o*- and *e*-rays, double refraction, Polarizing beam-splitters and waveplates. Faraday effect, Kerr effect

Ray Optics **[8]**
Fermat's principle, Matrix method, Thick lens, Optical instruments, Aberration: spherical and chromatic

Interference **[10]**
Superposition of waves, Huygens' Principle, Young's experiment, coherence, Interference by division of wavefront and division of amplitude. Multiple beam interference, Interferometers.

Diffraction of Light **[8]**
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.

PHYS0391: Physics Laboratory-2

1. Prism Spectrometer
To get familiar with spectrometer, Determination of the refractive index of a prism for various wavelengths of Sodium spectrum and verification of Cauchy's relation by plotting a dispersion curve using a Prism Spectrometer

2. Series LCR Resonance Circuit
To study the frequency response and to find resonance frequency of L-C-R series circuit. Finding the quality factor and band width in LCR series circuit, Analysis of phasor diagram and determination of resistance of inductor coil

3. Study of Mutual Inductance
To examine the effect of magnetic inductance of a given circuit and determination of mutual inductance

4. Study of Optical Activity with Polarimeter
To calibrate a polarimeter and determine the specific rotation of an optically active substance

5. Interference by Newton's ring
To determine the the radius of curvature of a plano-convex lens by using Newton's rings.

6. Diffraction by double slit
To study diffraction of light by using double slits and determination of unknown wavelengths.

Semester-4

PHYS0401: Classical Mechanics [50 Lectures]

Rigid Body Dynamics [7]

Demonstration of gyroscopic motion,Rotation about a fixed axis, Moment of inertia tensor, Products of inertia, Principal axis, Precession of top due to weak torque (formal derivation of gyroscopic motion), Euler's equation and its solution for symmetric rigid bodies.

Lagrangian and Hamiltonian Formalism [14]

Variational Principle in Mathematics, Principle of least action, Virtual displacement, D'Alembert's principle, Principle of virtual work, Generalised coordinates, Constraints and degrees of freedom,Lagrange's equations of motion for conservative holonomic systems, Generalised momentum, Cyclic coordinates, Application to simple cases, Construction of Hamiltonian using Legendre transformation, Hamilton's equations of motion and its application to simple cases, Relation between Hamiltonian and total mechanical energy in various cases, Noether's theorem: Symmetries and conservation principle

Small Oscillations [4]

Secular equation for small oscillations and its solution: Double pendulum, Weakly coupled pendulum, Normal coordinates and modes.

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

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.

PHYS- 0402: Quantum Theory and Special Relativity [50 Lectures]

Historical Development [8]

Black body radiation, Planck's formula, de Broglie hypothesis, Spectrum of light, Bohr model for hydrogen like ions, experimental evidences, Franck-Hertz experiment, Wilson-Sommerfeld quantization, Compton effect, Electron double-slit experiment, Davisson-Germer experiment, Heisenberg's uncertainty principle.

Development of Wave Mechanics [17]

Concept of wave function, Wave packets, Group and phase velocities, Principle of superposition, Operator formulation, Observables, Expectation values, Ehrenfast theorem, Commutation relation, Schrodinger equation, Probabilistic interpretation of the wave function, Properties of the solution of Schrodinger equation, Stationary states, Free particle, Simple potential problems, Modern applications.

Special Relativity [25]

Galilean relativity, Inconsistency with electromagnetic theory, Michelson-Morley experiment, Einstein's Principle of Relativity and a new Concept of Spacetime, Kinematics and Paradoxes, Lorentz Transformations and velocity addition.

Tensor calculus: Covariant derivative,Relativistic Energy momentum, Four vectors and transformation properties, Simple applications to particle decay and elastic collision, Aberration, Doppler effect: examples in modern research, Incompleteness of special relativity, Non-inertial reference frame and the equivalence principle.

PHYS0491: Physics Laboratory-3

1. Interference Using Fresnel Bi - prism
To understand the use of Fresnel bi-prism to divide the wavefront of a monochromatic, coherent beam of light producing an interference pattern and measurement of wavelength

2. Diffraction Grating Spectrometer
(i) To get familiar with the use of diffraction grating spectrometer.
(ii) Measurement of certain wavelengths of spectral lines of mercury vapour

3. Polarization by Reflection
Introduction to the method of producing linearly polarized light and testing the electromagnetic theory of reaction of polarized light from a dielectric surface, as expressed in Fresnel's equations

4. Verification of Fourier Series
To understand a parallel LCR resonant circuit and its use for Fourier analysis of periodic voltages

5. Study of Magnetic Hysteresis
To study the phenomena of magnetic hysteresis and determination of ferromagnetic constants.

6. Basic Electronic Circuits:
To become familiar with the functionality of a diode in circuits by using diodes as
(i) half wave, (ii) full wave and (iii) bridge rectifiers. Use of capacitors and inductors as basic filters.
(ii)

PHYS-0501: Quantum Mechanics [50 Lectures]

Schrodinger Equation and its Solutions [30]

Solution of the Linear Harmonic Oscillator potential: eigenvalues and eigen functions, Quantization by operator method, Coherent State, Number operator, Few applications in Physics, Stimulated Emission, Einstein's coefficients, Physics of Lasers, Hydrogen atom problem: Central force problem, Reduction to one dimension, Angular momentum – eigenvalues and eigenfunctions, SphericalHarmonics, Angular momentum Commutation, Concept of Spin, Addition of angular momentum, Many electron Systems, Pauli exclusion principle , LS and JJ coupling.

Approximate Techniques and Applications [12]

Semi-classical approach: vector atom model, Schrodinger equation in a static electromagnetic field, Spin-orbit interaction, Experiments with spin half particles: Stern Gerlach experiment, Larmor precession, Zeeman effect (normal & anomalous), Paschen-Back effect, Diatomic molecules-rotational and vibrational levels, basic ideas about molecular spectra, Raman Spectra

Formalism [8]

Linear Vector Spaces and linear operators, Hilbert space, Eigen functions of a Hermitian Operator, Uncertainty Principle, Dirac Notation, Heisenberg equation of motion, Symmetries in Quantum Mechanics

PHYS0502: Electronics [50 Lectures]

Semiconductor Devices [16]

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.

Bipolar junction transistor (BJT): construction, current amplification mechanism, common-base configuration and α, common-emitter configuration and β, common-collector configuration and emitter follower

BJT biasing, stability, load line and Q-point, transistor as voltage amplifier, hybrid parameters, Elementary circuit theory, Superposition theorem, Thevenin's theorem, Norton's theorem, 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

Amplifiers and Oscillators [8]

Positive and negative feedback, voltage and current feedback, advantages of negative feedback, Barkhausen criterion for sustained oscillation, Hartley and Colpitts oscillators, Wien bridge oscillator, crystal oscillator.

Operational Amplifier [10]

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

Digital electronics [10]

Decimal, binary and hexadecimal numbers, Boolean algebra, logic gates: AND, OR, NOT, Ex-OR, NAND and NOR, 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: introduction to flip-flop.

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.

PHYS0503: Thermal and Statistical Physics

Historical developments of thermal physics [8]

Kinetic theory of gases, Speed distribution, Mean free path, Equipartition of energy, Transport phenomena,Boltzmann approach. Behaviour of non-ideal classical gas.

Effects of Thermal Noise [3]

Brownian motion, Random walk, Langevin's approach, Einstein's theory.

Laws of Thermodynamics [12]

Basic concepts, Zeroth law of thermodynamics, Concepts of thermal equilibrium and equation of state,Dual nature of heat and energy, First law of thermodynamics, Internal energy, Thermodynamic variables, State function, Extensive and intensive variables, Carnot engine and concept of thermal entropy, Thermodynamic potentials, Maxwell relations, Thermodynamic equilibrium of phases, Heat theorem and third law of thermodynamics. Entropy and disorder.

Limitations of Thermodynamic Approach [4]

Absolute measure of internal energy, Realisation of third law of thermodynamics, Statistical description of states, Phase space, Liouville's theorem, Probabilistic approach, Isolated system, Concept of equal a priori probability, Statistical definitions of temperature and entropy, Statistical ensembles.

Formalisms and Applications of Classical Statistical Mechanics [14]

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 non-interacting spin systems. Ideal gas, Equation of state, Energy, Specific heat. Maxwell-Boltzmann distribution, Entropy of ideal gas, Gibbs' paradox. Applicability criteria of classical statistics.

Developments and Applications of Quantum Statistical mechanics [9]
Spin dependent quantum states of system of particles, Fermi-Dirac 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. Bose-Einstein statistics, Simple applications in black body radiation, Bose-Einstein condensation.

PHYS0591: Physics Laboratory-4 (Numerical Methods and Computing)

Computer Language (one of FORTRAN/C/C++/Python) [10]
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.

Numerical Methods [20]

Solution of simultaneous linear equations by Gauss-Siedel method, Finding real roots by Bisection and Newton - Raphson method, Calculations of derivatives by forward difference and central difference method, Integration by trapezoidal method, Simpson's rule, and statistical method, Solving ODE by Euler, modified Euler, Taylor series, Runge-Kutta method.

Data Analysis and Applications [20]
Sorting of data, Statistical analysis, Curve fitting, Random walk, Matrix operations (addition, subtraction, multiplication, transpose).

PHYS0592: Physics Laboratory 5

1. **Zener Diode:** (i) current-voltage characteristics (ii) application as voltage regulator (ii) verification of load and line regulations.
2. **Regulated power supply:** (i) concept of upgrading the regulation by providing current gain and (ii) implementation in circuit using transistor with Zener diode.
3. **Bipolar Junction Transistor (BJT):** (i) static and dynamic output characteristics of a transistor and (ii) determination of *h* parameters.

4. **BJT Amplifier:**To design the circuit for a transistor voltage amplifier in common-emitter mode and study the effects of the amplitude and the frequency of the input signal.
5. **Field-Effect Transistor:**To draw the output characteristics of FET and to determine (i) mutual conductance, (ii) drain resistance and (iii) amplification factor.
6. **Logic Gates:** (i) Realizing AND and OR gates with diodes and NOT gate with transistor (ii) Construction of different logic gates (or logic circuits) using universal gates.

Semester-6

PHYS-0601 Nuclear and Particle Physics [50 lectures]

Nuclear structure and properties [15]

Properties of nuclei - size, shape, charge distribution, binding energy, spin, electric and magnetic moment, parity, 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: validity and limitations, Nuclear stability: liquid drop model and semi-empirical mass formula, Extreme single particle shell model, Magic numbers.

Unstable Nuclei [10]

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 [10]

Conservation principles, Q value and threshold, Types of nuclear reaction, Direct reaction, Bohr's postulate of compound nucleus formation, Fission: spontaneous and induced, Energy and mass distribution of fragments, Bohr-Wheeler theory of fission, Chain reactions, Nuclear reactors, Fusion: explanation from liquid drop model.

Elementary Particle Physics [15]

Four fundamental interactions, Quantum numbers: mass, charge, spin-isospin, strangeness, parity, hypercharge, Conservation laws, Particle classification: hadron and lepton, Elementary idea about quark model of hadrons: baryons and mesons, Gell-Mann plot, Phase space calculations, Production and decay processes, Elementary discussion of key experiments that led to the current understanding of electro-weak and strong interaction (Standard Model), Introduction to physics beyond the Standard Model (neutrino mass and oscillation).

PHYS0602:Solid State Physics [50 Lectures]

Free Electron Theory of Metals [6]

Relaxation time, Mean free path, Mobility and thermal conductivity. Drude model of electrical conductivity, Wiedemann-Franz Lorentz relation, Hall effect.

Crystal Structure and Bonding in Solids [10]

Crystalline periodicity, crystal symmetry, Bravais lattice, Reciprocal lattice, Position, directions and planes in crystals,Close-packed structures,Bragg's diffraction, Laue condition of X-ray diffraction, Determination of crystal structure with X-rays,Different types of bonding – ionic, covalent, metallic, van der Waals and hydrogen type.

Energy Band Structure [9]

Periodic potential in a crystalline solid, Bloch theorem, Kronig-Penny model and the formation of energy band, Allowed and forbidden energy gaps, Number of electrons in a band, Effective mass tensor, Electrons and holes, Metals, insulators and semiconductors.

Lattice Vibration and Specific Heat of Solids [7]

One dimensional monatomic lattice, periodic boundary condition and vibrational modes of 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, Internal fields of solids,Clausius-Mosotti relation.

Magnetic Properties of Solids [12]

Magnetic susceptibility, Diamagnetism of core electrons, Paramagnetism,Langevin equations for dia and paramagnetism, Curie's law, Quantum theory of paramagnetism for spin-half system. Spontaneous magnetization and ferromagnetic properties of solids, Temperature variation of spontaneous magnetization, Curie-Weiss law, Domain structure and hysteresis in ferromagnets.

Elective Paper PHYS0603

PHYS0603-A: Astrophysics and Cosmology [50 Lectures]

Introduction to Observational Astronomy [7]

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 spectral classification, Saha equation, Hertzsprung-Russell diagram, Stellar structure -hydrostatic equilibrium, Polytropes, Lane-Emden equation : analytic solutions, Stellar energy generation-nucleosynthesis, Radiative transfer, Stellar evolution, Fate of massive stars: brown dwarfs, supernovae, Compact objects: white dwarfs, neutron stars and black holes.

Introductory extragalactic Astrophysics [10]

Galaxy-classification, Galactic structure, Milky Way galaxy, Active galaxies, Structure of the Universe.

Cosmology **[15]**

Background Smooth Universe: Observational triumphs of cosmology, Olber's paradox, Hubble's law and the expanding Universe, Big Bang theory, Redshift, Scale factor, Cosmological principle: homogeneity and isotropy, homogeneity and isotropy, Newtonian cosmology, Friedmann equation, Conservation and acceleration equations, Different components of the Universe, Multi-component Universe,Equations of state, Distance measures in cosmology, Thermal History of the Universe, Dark matter, Dark energy, Observational signatures of the perturbed Universe

PHYS0603-B: Analog and Digital Electronics

Semiconductor Materials and Devices **[14]**

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, Gunn diode

Optoelectronics: 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.

Amplifiers **[8]**

Properties of voltage and current amplifiers, transistor power amplifier, tuned and wide band amplifier, class A, class B and class C amplifiers, push-pull amplifier, multistage amplifier, types of coupling: direct, RC and transformer.

Operational Amplifier **[8]**

Linear and nonlinear op-amp circuits, use of negative feedback, instrumentation amplifier, voltage-controlled current source, precision rectifier, active filter: low pass, high pass, band pass and band reject, comparator with zero and non-zero references, multi-vibrator and waveform generators, current booster, regulated power supply with the use of transistor.

Digital Electronics **[10]**

Logic families: DTL, TTL and MOS, Combinational and sequential logic circuits, Multiplexer, Demultiplexer, Decoder, Encoder, Diode ROM, Flip-flops: RS, D, JK, JK master-slave, Clock and timer circuits, Shift registers and counters and their types, Digital-to-analog and analog-to-digital converters, Memory.

Instrumentation **[5]**

Cathode ray oscilloscope: construction and measurement of electrical quantities, Introduction to microprocessor, block diagram of 8085, Types of instructions, Op-code, Brief idea of microprocessor programming and interfacing.

Signal Transmission 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.

PHYS0603-C: Quantum Optics and Quantum Information

Quantum Optics **[30]**

Coherent states of light, Phase space picture, Atom-electromagnetic field interaction,Jaynes-Cummings model, Squeezed states of light, coherence functions, dissipative interactions and decoherence, Quantum noise and its reduction, Quantum non-demolition measurements, Interferometry with squeezed states, Applications in interferometric experiments.

Quantum Information **[20]**

Classical information, Shannon entropy, Quantum density operator, entangled states,Bloch sphere, von Neumann entropy, Quantum measurement theory, Einstein-Podolsky-Rosen paradox, Bell's theorem, Greenberger-Horne-Zeilinger equality, Optical test of local realistic theories and Bell's theorem, Applications to quantum cryptography.

PHYS0691: Physics Laboratory 6

1. **Relaxation Oscillator:**To design astable multivibrator using transistors and passive components and to study its output waveform.
2. **Operational Amplifiers:** (i) applications involving linear and nonlinear amplifications, such as inverting amplifier, non inverting amplifier, comparator and Schmitt trigger (ii) realizing mathematical operations in terms of voltage, such as adder, differential amplifier, differentiator and integrator,
3. **Sinusoidal Oscillator:**Designing Wien bridge oscillator using OpAmp and lead-lag circuit and studying its output waveform using CRO.
4. **Sequential Logic Circuits**: Fabrication of RS, D & JK flip-flop using universal gates and to verify the truth tables.
5. **Semiconductor Resistivity:** (i) Determination of resistivity of a semiconductor by four probe method at different temperatures and (ii) estimating the band gap of the material.
6. **Hall Effect:** Determination of the concentration of majority carriers of a semiconductor by measuring Hall voltage.

PHYS0692:Supervised Reading/Project