COURSE MODULE FOR B.Sc PHYSICS HONOURS STUDENTS

PROF. CHANDRANATH BANDYOPADHYAY

YEAR	TOPICS	NO OF LECTURES
PART- I	**Thermal Physics (25)**	
	1. Thermometry. Gas thermometer. Platinum resistance thermometer. Radiation pyrometer.	**2**
	2. Kinetic theory of gases. Basic assumptions of the theory. Deduction of the perfect gas equation. Temperature in kinetic theory. Probability of occurrence of an event, theorems of total probability and compound probability. Maxwellian distribution function of molecular speeds. Mean speed, root-mean-square and most probable speed. Degrees of freedom of molecules. Boltzmann's extension of Maxwell's distribution law. Law of equipartition ofenergy (Statement and applications). Specific heat of gases. Ratio of specific heats at constant pressure and volume.	**8**
	3. Molecular collisions. Probability of a free path x. Mean free path. Effect of distribution of molecular speeds. Transport phenomena in gases. Transport of momentum, energy and mass. Coefficient of viscosity of gases and qualitative discussion of its variation with temperature and pressure. Thermal conductivity of gases. Diffusion. Simplified derivation of the coefficient of self-diffusion.	**5**
	4. Real gases. Deviation from the perfect gas equation. Results of the experiments of Andrew and Amagat. Virial expansion and virial coefficients. Van der Waal's equation of state. Arguments for pressure and volume corrections. Critical constants. Law of corresponding states. Equation of state of an ideal gas from the virial theorem. Qualitative idea regarding molecular forces.	**5**
	5. Heat conduction in solids. Conductivity and diffusivity. Steady state solution of one-dimensional heat flow equation. Heat flow in three dimensions with spherical and cylindrical geometry. Ingen-Hausz experiment.Periodic flow of heat in one dimension. Wiedemann-Franz law.	**5**

	Ray Optics (20) 1. Wave picture of light. Wavefront and light rays. Short wavelength limit and geometrical optics. Fermat's principle and its application to reflection and refraction at plane and spherical surfaces. Paraxial theory of thin spherical lens systems. Matrix method in paraxial optics. System matrix. Matrix description of image formation. Helmholtz-Lagrange law for magnification. 2. Aberrations. Monochromatic aberrations of a thin lens. Spherical aberration (detailed derivations are not required). Abbe's sine condition. Aplanatic points. Oil immersion objectives of high power microscopes. Chromatic aberration. Achromatic doublet. Separated doublet with no chromatic aberration. 3. Field of view of optical instruments. Ramsden and Huyghens eye pieces. Reflecting and refracting telescopes. Angular magnification. Simple and compound microscopes. Resolving power (qualitative discussion). 4. Elements of fiber optics. Numerical aperture. Step-index and graded-index fibers. single and multimode fibers, merits and demerits: in view of intermodal dispersion.	**7** **6** **4** **3**
PART- I I	**Thermal Physics II (30)** 1. Thermodynamics. Macroscopic and microscopic points of view. Examples of thermodynamic systems. State variables. Thermal equilibrium. Zeroth law of thermodynamics. Concept of temperature. Thermodynamic processes. Differential change of state. Volume expansivity. Isothermal compression. Intensive and extensive quantities. Work and its path dependence. Work in quasi-static processes. Work and heat. Adiabatic work. Internal energy function. First law of thermodynamics. Differential form. Applications of the first law. Heat capacities C_P and C_V. Adiabatic and isothermal elastic moduli. 2. Conversion of heat into work and *vice versa*. Heat engines. Efficiency of Carnot cycle. Second law of thermodynamics . Different formulations of the law and their equivalence. Refrigerator. Idealized refrigeration cycle. Reversible and irreversible processes. Conditions for reversibility. Carnot's theorem. Kelvin temperature scale. Cyclic process. Clausius theorem. The concept of entropy. Entropy forms of the first and second laws of thermodynamics. Entropy change of an ideal gas. Entropy of a mixture of gases. TS diagram. Entropy change in reversible and irreversible processes. Principle of the increase of entropy. Entropy and unavailable energy.	**10** **10**

	Entropy and disorder. Entropy and information. 3. Maxwell's thermodynamic relations. Heat capacity equations. Isothermal and adiabatic compressibilities. Change of state. Clausius-Clapeyron equation. Enthalpy. Porous-plug experiment. Joule-Thomson effect. Helmholtz and Gibbs functions. Conditions for natural change and thermodynamic equilibrium. Chemical potential. Gibbs' phase rule (statement only) and its applications. Triple point. 4. Thermoelectricity. Seebeck, Peltier and Thomson effects. Thermoelectric power. Application of thermodynamics to thermoelectric circuits. 5. Cooling by adiabatic demagnetization. Nernst heat theorem. Unattainability of absolute zero of temperature. Third law of thermodynamics.	**5** **3** **2**
	Mathematical Methods II (15) 1. Linear vector spaces. Examples. Linearly independent set of vectors. Basis and dimensionality of a vector space. Scalar product. Orthogonality of vectors. Linear transformation. Linear operators. 2. Matrix algebra. Transpose of a matrix. Hermitian, orthogonal and unitary matrices. Matrix for rotation in twoand three dimensions. The inverse of a matrix. Solution of a system of linear equations by matrix method. Eigenvalues and eigenvectors of a matrix. Properties of eigenvectors and eigenvalues of Hermitian and unitary matrices. Matrix representations of Linear operators. Similarity transformation.	**5** **10**
PART- III	**Quantum Theory(13)** 1. Application of Schroedinger equation to simple systems. Free particle or particle in a constant onedimensional potential. The step potential. Boundary conditions on the wavefunction and its derivative at a point where the potential function has a finite discontinuity. Solution of the step potential problem with energy less than or greater than the step height. Reflection and transmission coefficients. Finite potential barrier. Barrier penetration. Tunnelling, Reflection and Transmission coefficients. The infinite square well potential or particle in a box. Energies and wavefunctions of the ground and excited states. Ground state energy from the uncertainty principle, symmetric and antisymmetric solutions. The simple harmonic oscillator. Energy eigenvalues. Ground state wavefunction. Zero-point energy from the uncertainty principle. Parity of the eigenfunctions. Nodes of the eigenfunctions. Schroedinger equation in three dimensions. Particle in a rectangular box. Eigenfunctions and energy	**13**

	eigenvalues. Degeneracy	
	Nuclear Physics (40)	
	1. Nuclear constituents. Summary of important properties of protons and neutrons. Nuclear energy scales and sizes. Alpha particle scattering. Derivation of Rutherford's formula. Analysis of Geiger-Marsden experiments. Deviation from Rutherford's scattering formula. Estimation of nuclear radius. Determination of atomic masses by Bainbridge type mass spectrograph. Unified mass unit (u). Isotopes. Isobars. Mass defect. Packing fraction. Nuclear binding energy. Average binding energy per nucleon. Binding energy curve. Neutron and alpha separation energy. Nuclear radius. Nuclear density. Magnetic moment of nuclei. Nuclear magneton. Outline of Rabi's method for the determination of magnetic dipole moments of nuclei. Electric quadrupole moment of nuclei. Electric quadrupole moment and nuclear shape. Nuclear spin and its determination from the study of hyperfine structure.	**10**
	2. Nuclear models. Stable and unstable nuclei, Independent particle and strongly interacting models. Liquid drop model. Binding energy on the basis of liquid drop model. Shell model. Experimental evidence in support of the model. Magic numbers. Spin-orbit interaction. Ground state angular momentum.	**4**
	3. Bethe-Weizsacker semi-empirical formula. Volume, surface, Coulomb, asymmetry, pairing and shell terms. Derivations of the Coulomb and asymmetry terms. Coulomb energy difference between mirror nuclei. Massparabola. Most stable nuclei. Stability of nuclei. Discovery of the neutron. Detection of neutrons. Neutron Magnetic moment. Nuclear forces. Qualitative discussion on range, strength, exchange nature, charge independence, and saturation of nuclear forces.	**5**
	4. Natural, and artificial radioactivity. Decay constant, half life, and mean life. Activity and its units. Radioactive dating. Energetics of alpha decay. Range of alpha particles. Simplified account of Gamow's theoryof alpha decay. Geiger-Nuttall law. Beta decay. β_-, β_+ decays. Pauli's Neutrino hypothesis, Outline of Fermi theory of beta decay. Parity non conservation. Madam Wu's experiment. Electron capture. Continuous nature of the beta energy spectrum. Gamma decay. Pair creation and annihilation. Energetics.	**5**

	Interaction of gamma rays with matter. Photoelectric, Compton and pair production processes (No details derivation are required). 5. Mechanisms for the energy loss of charged particles. Stopping power (no deduction required). Ionization chamber. Variation of pulse size with applied voltage. Qualitative explanation of the ion recombination,saturation, proportional, Geiger, and continuous discharge regions. Proportional counter. Geiger-Muller counter. Self-quenching. Dead time and recovery time. Linear accelerator. Cyclotron. Working principle. Betatron. VEC(elementary idea). 6. Nuclear Fission, Energy release, Emission of neutrons. Theory of spontaneous fission. Self-sustaining chain reaction. Nuclear reactor. Classification of reactors. Breeder reactor. Thermonuclear reactions and fusion. 7. Nuclear reactions. Cross-section of a nuclear reaction. Laboratory and centre of mass systems. Conservation principles governing nuclear reactions. Threshold energy of an endo-ergic reaction. Compound nucleus. Experimental verification of the compound nucleus hypothesis. Mention of Ghoshal experiment. Q-value of a nuclear reaction. Nonrelativistic Q-equation. 8. Classification of elementary particles. Leptons, mesons, and baryons. Exact and approximate conservation laws. Fundamental interactions. Quark model (elementary idea).	**5** **4** **4** **3**

COURSE MODULE FOR B.Sc PHYSICS HONOURS STUDENTS

DR. SISIR KUMAR GARAI

YEAR	**TOPICS**	**NO OF LECTURES**

PART- I	**Mechanics I (41)**	
	1. Fundamental and derived units. Dimensions of physical quantities. The principle of dimensional homogeneity. Limitations of dimensional analysis.	**2**
	2. Review of Newton's laws of motion. Variable mass problems. Rocket motion. Concepts of work, power, and kinetic energy. Work-energy theorem. Conservative force fields. Potential energy. Galilean invariance. Conservation of linear momentum and energy. Tangential and normal components of velocity and acceleration. Angular momentum and torque. Conservation of linear and angular momentum, and energy of a system of particles. Impulse. Motion of the centre of mass and motion relative to the centre of mass. Collisions. Direct and oblique collisions. Examples of elastic and inelastic collisions. Collisions in one and two dimensions.	**10**
	3. Motion of a rigid body about an axis. Moment of inertia. Angular momentum and kinetic energy in terms of angular velocity and moment of inertia. Theorems of parallel and perpendicular axes. Moment of inertia of common symmetrical bodies. Radius of gyration. Product of inertia. Principal axes. Ellipsoid of inertia. Compound pendulum. Kater's reversible pendulum (detailed discussion of various corrections is not required).	**8**
	4. Non-inertial frames of reference. Fictitious forces. Rotating coordinate systems. Velocity and acceleration in a rotating coordinate system. Centrifugal and coriolis forces. Direction of ocean currents and river flows. Motion of a particle relative to the earth.	**7**
	5. Central forces. Two-body central force problem and its reduction to two one-body problems. Reduced mass. Important properties of motion under central force. Velocity and acceleration and their radial and transverse components. Differential equation of the orbit. Inverse square law of force. Conditions for parabolic, elliptic and hyperbolic orbits. Kepler's laws. Motion of artificial satellites. Geocentric satellites.	**8**
	6. Motion of ideal fluids. Streamlines and streamline flow. The continuity equation. Euler's equation for an incompressible fluid. Steady flow. Bernoulli's theorem and its applications. Toricelli's expression for the velocity of efflux of a liquid. Venturimeter.	**6**

PART- I I	**Electromagnetics (38)** **1.** Steady electric current. Current as moving charges. Equation of continuity. Ohm's law. Simple microscopic picture of metallic conduction. Drift velocity. Current density. Electrical conductivity. Electromotive force. Resistance networks. Kirchoff's laws. Wheatstone bridge (Detailed calculations on sensitivity etc. are not required). Kelvin's double bridge.	**8**
	2. Oersted's experiment. Ampere's law. Force between current elements and between two infinitely long wires carrying currents. Magnetic induction **B**. Biot-Savart law. Divergence of **B**. Integral form of Ampere's law. Simple applications. The vector potential and its properties. Calculation of **B** in terms of the vector potential (straight wire, circular coil, and solenoid). Magnetic dipole. Potential energy in a uniform magnetic field. Force on a dipole in an inhomogeneous magnetic field. Magnetic dipole-dipole interaction. Lorentz force. Motion ofcharged particles in a uniform magnetic field. Cyclotron frequency. Motion of charged particles in crossed electric and magnetic fields. Measurement of the charge *e* and the (*e*/*m*) ratio of electrons.	**12**
	3. Faraday's law of electromagnetic induction in integral and differential forms. Motional emf and motional electric field. Self and mutual inductance. Self inductance of a long solenoid and solid cylindrical conductor. Galvanometers. Electromagnetic damping. Dead beat and ballistic galvanometers (solution of equation of motion may be assumed). Fluxmeter.	**6**
	4. Growth and decay of currents in circuits with L and R. Oscillations in LC circuits. Charging and discharging of capacitors in CR and LCR circuits. Alternating current. AC circuit analysis. Use of complex numbers. Impedance and reactance. Currents in LR, CR, and LCR circuits with sinusoidal emf. Series and parallel resonance. Quality factor. Power consumed in ac circuit. Power factor. Wattmeters. Rotating magnetic fields. AC and DC motors and generators. Transformer. Vector diagrams with and without load.	**12**

PART- III	**Electronics (24)** 1. **Principle of Modulation and Demodulation :** Need for modulation, types of modulation; amplitude modulation – analysis modulation index, frequency spectrum, power analysis**,** collector modulator circuit and its working; Envelope detector using diode. Frequency modulation (single tone) – analysis, peak deviation, FM index, frequency spectrum, Cursson's rule. Principle of detection of FM signal. Phase modulation-relation between FM and PM.	**7**
	2. **Operational Amplifier:** Properties of Op-amp. Need of OP-amp. Input-output characteristics of an ideal opamp. Common mode gain and difference mode gain. CMRR. Op-amp as in ideal difference amplifier. Ideas of inverting and non- inverting inputs. Characteristics of ideal and practical Op-amps. Virtual ground. Application of Op-amp as inverting amplifier. Unity gain buffer, adder, phase shifter, integrator, differentiator and differential amplifier. Basic principle of analog to digital converter. Digital-to-analog converter circuit.	**5**
	3. **Digital Electronics:** Number systems – decimal, binary, octal, hexadecimal and their inter-conversions (integer and fraction), binary arithmetic addition and subtraction;. Boolean algebra - basic postulates and laws. De Morgan's theorem- statement and proof. Simplification of Boolean expressions using algebraic and graphical methods. Karnaugh map – techniques and examples (upto 4 variables) . Basic logic gates with their truth tables : AND, OR, NOT and Ex-OR gates. NOR and NAND gates as universal gates. Implementation of OR and NAND gates with diodes and resistors. Combinational logic circuits – Half adder, full adder, binary comparator, multiplexer and de-multiplexer. Sequential logic circuits – SR, JK , D and T flip-flops.	**12**
	Special Theory of Relativity (30) **1.** Galilean and Newtonian relativity. Electromagnetism and Newtonian relativity. The ether concept. Bradley's experiment on stellar aberration. Fizeau's experiment. Michelson-Morley experiment. Motivation behind the experiment. Brief discussion on the various theories of *ad hoc* nature aimed at explaining the null result of the experiment. Einstein's postulates of the special theory of relativity. Relativity of simultaneity. Lorentz transformation equations and their consequences. Length contraction. Time dilation. Decay time of muons. Law of addition of velocities along the same direction. Doppler effect, Head light effect.	**10**

	2. Invariance of the principle of conservation of linear momentum. Variation of mass with velocity. Experimental verification. Covariant formulation of Newton's laws of motion. Dynamics of a single particle, Idea of mass-energy equivalence. The longitudinal and transverse mass. The transformation properties of momentum, energy ,mass and force. 3. Four vector formalism, Transformation of 4 vectors, four velocity, four momentum, Poincare & Minkowski 4-D representation. Geometrical interpretation of Lorentz transformation equation, space time interval and its invariance, space like and space like intervals, light cone, past, present and future, proper length, proper time interval, length contraction and time dilation from Minkowski 4-D representation. 4. The intererdependence of electric and magnetic fields. Transformation equations for **E** and **B**. Invariance of Maxwell's equations under a Lorentz transformation.	**8** **7** **5**

COURSE MODULE FOR B.Sc PHYSICS HONOURS STUDENTS

DR. ATANU DAN

YEAR	TOPICS	NO OF LECTURES
PART- I	**Mathematical Methods I (18)** **1.** Bessel's differential equation. Series solution. Bessel functions of the first and second kinds. Recurrence relations involving Bessel functions of the first kind. Legendre's differential equation. Legendre polynomials. Rodrigue's formula. Generating function of Legendre polynomials. Recurrence relations involving Legendre polynomials. Orthogonality of Legendre polynomials. **2.** Partial differential equations. Hyperbolic, parabolic and elliptic differential equations. Solution of Laplace's equation in Cartesian, spherical polar and cylindrical coordinates by the method of separation of variables. Boundary	**7** **5**

	and initial value problems. **3.** Fourier series. Dirichlet conditions. Change of interval. Expansions of odd and ecen periodic functions. Halfrange series. Fourier analysis of typical waveforms. Parseval's formula. Fourier transformation and its simple poroperties: elementary idea .	**6**
	Waves and Oscillation (20) 1. Rotating vector and complex exponential representation of simple harmonic motion (SHM). Superposition of two harmonic oscillations. Lissajous figures. Composition of many harmonic oscillations with constant phase and frequency difference. Beat phenomenon. Free oscillations of systems with two degrees of freedom (two pendulums coupled by a spring; a string with two beads). Normal modes and normal vibrations. Normal modes of coupled oscillators. 2. Damped harmonic oscillator. Power dissipation. Q factor. Damped driven harmonic oscillators. Steady state oscillation under harmonic driving force. Resonance. Sharpness of resonance. 3. Waves in a continuous medium. Elastic waves in solids, liquids and gases. Dispersion. Phase and group velocity. Energy transport by a traveling wave. Relative and absolute intensity. Decibel. Standing waves. Kundt's tube. 4. Brief discussion on (a) resonators, (b) microphones, (c) ultrasonic generators.	**6** **6** **5** **3**
PART- I I	**Wave Optics (40)** 1. Experimental evidence of light as an electromagnetic phenomenon. Electromagnetic spectrum. Wave equation. Plane, cylindrical, and spherical waves. Plane of vibration. Wavefront. Huygens' principle. Application of the principle to reflection and refraction phenomena. 2. Interference. Spatial and temporal coherence. Holography (brief qualitative discussion). Two-beam interference. Interference by division of wavefront and division of amplitude. Young's double slit experiment. Fresnel's biprism. Lloyd's mirror. Michelson's interferometer. Circular and straight fringes. Visibility of fringes. Multiple-beam interference. Interference in thin films. Newton's rings. Fabry-Perot interferometer. Intensity formula. Coefficient of finesse. Resolving power of a Fabry-Perot interferometer. 3. Diffraction of light. Fresnel diffraction. Division of wavefront into half-period zones. Zone plate. Rectilinear propagation. Fraunhofer diffraction. Diffraction due to (i) a single and (ii) two parallel slits. Plane diffraction grating. Rayleigh's criterion for the resolution of spectral lines. Resolving powers of telescope, microscope, and prism. Resolving and dispersive	**6** **10** **10**

	power of a plane diffraction grating. 4. Light propagation through anisotropic crystals. Fresnel equation. Possible types of waves. Dependence of group velocity on direction. Optic axis. Uniaxial and biaxial crystals. Double refraction or birefringence. Ordinary and extraordinary rays. Huygens' construction for the propagation of plane waves through uniaxial crystals. Analysis of polarized light. Half-wave and quarter-wave plates. Nicol prism. Babinet's compensator. Optical activity. Fresnel's explanation. Molecular basis of optical activity. Electrooptic and magnetooptic effects. Faraday effect. Verdet's constant. Kerr effect. Kerr cell as a fast optical shutter. Use of a Kerr cell in the determination of the speed of light. Pockels effect. 5. Ideas of stimulated and spontaneous emission. Ordinary and laser light. Characteristics of laser light. Principles underlying the operation of a laser. Population inversion. Pumping. Optical resonator. Ruby laser. He- Ne laser.	**10** **4**
PART- III	**Electronics (38)** 1. **Physics of Vacuum Tube Devices**: Thermionic emission. Richardson's equation (statement and explanation only). Fermi level and work function of solids. Vacuum diodes and triodes-- their volt ampere characteristics. Qualitative explanation of characteristics. Triode parameters (μ , r_p, g_m). Functional structure and operation of a Cathode Ray Oscilloscope. 2. **Physics of Semiconductors:** Classification of materials based on electrical conductivity. Metals, insulators and semiconductors. Eenergy band concept. Band diagram. Concept of hole. Intrinsic and extrinsic (impurity) semiconductors. Elemental and compound semiconductors. Law of mass action. Majority and minority carrier densities. Effective mass. Mobility of holes and electrons. Direct and indirect band gap semiconductors. Importance of silicon. 3. **Solid State Two Electrode Device** : Rectifier diodes. Concept of diffusion and drift currents. Formation of depletion layer. Unbiased and biased p-n junctions. Derivation of the expression of junction currents. Discussion on I-V characteristics. Junction capacitance of forward-biased p-n junctions. Varactor diodes. Reverse recovery time. Switching speed. Avalanche and Zener breakdown of junction diodes. Zener diodes-- basic structure, I-V characteristics, applications. Tunnel diodes –basic structure, I-V characteristics, dynamic negative resistance. Photodiode – principle of operation, applications. LED – fabrication principle and applications. Metal semiconductor junction diode – special features. 4. **Power Supply Circuits**: Half wave and full wave rectifiers. Ripple factor,	**3** **4** **5**

	efficiency, dc. output voltage. Bridge rectifier. Capacitor filters. L-Section and π section filters (analysis not required). Voltage regulators – Zener diode-based regulators. Three terminal IC regulators (outline only).	**3**
	5. **Solid State Three Electrode Devices** : Bipolar junction transistor (BJT) – basic structure. n-p-n and p-n-p types, different methods of biasing, possibilities of emitter- base and collector-base junctions. CE, CB, CC configuration. I-V characteristics of input and output ports in CB and CE configurations, explanation of the characteristics. Introduction of α and β parameters. Cut-off, active, saturation and breakdown regions of transistor operation. DC models of BJT at different regions of operation. Field effect transistor – JEET and its IV characteristics, pinch-off voltage, applications. MOSFET – structure, specialties, classification of MOSFETs, enhancement and depletion types, typical applications; structure, I-V characteristics and application; SCR – structure, I-V characteristics and application.	**5**
	6. **Small Signal BJT Amplifier (Single Stage) :** Biasing problem of BJT. Operating point of a transistor amplifier. Typical biasing circuits – fixed bias, voltage divider bias with emitter resistor, bias stability consideration and stability parameters. Other biasing circuits – collector bias, emitter bias. AC equivalent circuit of BJT. Simplified h-parameter ac mode. Analysis of CE, CB and CC amplifiers for voltage gain, current gain, input resistance and output resistance. High frequency equivalent circuit of transistor. Miller effect. Single stage R-C coupled amplifier. Gain-bandwidth consideration. Half power frequency.	**5**
	7. **Feedback in Amplifiers** : Feed back principle. Negative and positive voltage feedback. Effect of negative feedback on the response of amplifier in terms of gain, stability, input impedance, output impedance (no mathematical deduction), bandwidth and distortion of the amplifier.	**2**
	8. **Special Purpose Amplifiers:** Cascaded BJT amplifiers – two stage RC coupled and transformer coupled amplifiers. Large signal amplifiers. Distinction between voltage and power amplifiers. Class A, class B and class C operation of amplifiers Class A power amplifier – expression of Concept of push-pull configuration.	**5**
	9. **Electronic Oscillators: Classification –** sinusoidal and relaxation, audio frequency and radio frequency, feedback and negative resistance; Barkhausen criterion and oscillator principle; R-C Phase Shift OscillatorWien bridge oscillator. Derivation of condition of oscillation. General reactance oscillator – circuit and derivation of condition and frequency of oscillation. Hartley and Colpitts oscillators. Astable multivibrator circuit using BJT – principle of operation and frequency of oscillation.	**6**

	Quantum Theory (28) 1. Wave like properties of particles. de Broglie's postulate. de Broglie wavelength. Phase velocity and group velocity of de Broglie waves, Wave-particle duality, Davisson-Germer experiment. Uncertainty principle and its implications. Heisenberg's thought experiment with gamma ray microscope. Young's double slit experiment with electrons/photons. Uncertainty principle as a consequence of wave packet description of particles.	**5**
	2. The concept of measurement in quantum theory. Specification of the state of a system in quantum theory. Representation of observables by hermitian operators. Operators associated with position, linear momentum, and kinetic energy. Simple properties of hermitian operators. Commutation relation between operators. Simple properties of hermitian operators. Eigenvalues and eigenfunctions of hermitian operators. Postulates of quantum theory regarding the results of measurement of an observable. Expansion postulate (discussion at an elementary level). Orthogonality and completeness.	**5**
	3. Plausibility arguments leading to Schroedinger's equation in one dimension. Consistency with de Broglie postulate, classical energy equation and the principle of superposition. The Schroinder equation as an operator equation. Generalization of the one dimensional Schroedinger's equation to three dimensions.for a particle in a potential V(**r**). The Schroedinger equation as an operator equation. Statistical interpretation of wavefunction. Probability density. Normalization. Expectation values. Schroedinger's time-independent equation. Stationary states. Behaviour of wavefunctions for bound and unbound states. Equation of continuity. Probability current density.	**9**
	4. Particle in a spherically symmetric potential. Form of the ∇^2 operator in spherical polar coordinates may be assumed. Method of separation of variables. Radial and angular parts of the wavefunction. Orbital angular momentum **L** = **r** x **p**. Operators for the components of **L**. Commutation relations involving L_x, L_y, L_z and L^2 . The forms of L_z and L^2 in spherical polar coordinates. Space quantization. Hydrogen atom problem, energy eigenvalues. Quantum numbers. Degeneracy. Explicit form of the ground	**9**

	state wavefunction. Probability density in the ground state.	

COURSE MODULE FOR B.Sc PHYSICS HONOURS STUDENTS

PROF. SUKLA RAJAK

YEAR	TOPICS	NO OF LECTURES
PART- I	**Mathematical Methods I** (32) **1.** Vector algebra and calculus: Scalars and vectors. Unit vectors. Scalar and vector products. Physical applications. Products of three or more vectors. Reciprocal vector triads. Ordinary and partial derivative of vectors. **2.** Scalar and vector fields with examples. Coordinate transformation. Notion of invariance. Gradient of a scalar field. Directional derivative. Divergence and curl of a vector field and their physical significance. Solenoidal and irrotational vectors with examples. Conservative vector field and scalar potential. **3.** Vector integration. Line integral. Path independence. Exact differential. Surface integral. Flux of a vector field. Volume integral. Divergence theorem. Stokes' theorem. Green's theorem in the plane. Green's second identity. Verification of the integral theorems in simple cases. (Proofs of the integral theorems are not required.) **4.** Orthogonal curvilinear coordinates. Unit vectors in curvilinear coordinate system. Arc length and volume element. The Jacobian and its properties. Cylindrical and spherical polar coordinates. The gradient, divergence, curl, and the Laplacian in cylindrical and spherical polar coordinates. **5.** The gamma function and its simple properties. Evaluation of gamma functions of half-integral arguments. Beta function. Relation between beta and gamma functions. Dirichlet's integral. **6.** Ordinary differential equations (ODE). Degree and order of an ODE.	**4** **5** **6** **6** **4**

	Solution of second-order linear homogeneous and inhomogeneous ODE with constant coefficients. Complementary function and particular integral. Second order ODE with variable coefficients. Linear independence. Wronskian. Regular and irregular singular points. Integration in series of second order ODE. Indicial equation. General solution of second order equations when roots of the indicial equation are (a) distinct and do not differ by an integer, (b) distinct and differ by an integer, (c) equal. (Proofs of theorems are not required) .	**7**
	Electrostatics (15) **1.** Multipole expansion of the electrostatic scalar potential. The monopole, dipole and quadrupole terms. Force and torque between two dipoles. The linear quadrupole. Stability of charges. Earnshaw's theorem (Statement and explanation). (5L) **2.** Conductors and mobile charges. Conductor in an electric field. Redistribution of charges on the surface of a conductor. Field near the surface of a conductor. Method of images. Applications to simple symmetric arrangements. Electrostatic coupling between conductors. Capacitance. Parallel plate, spherical, and cylindrical capacitors. Energystored in electrostatic field. **3.** Dielectric in an electrostatic field. Polarization. Local field. Electric susceptibility. Volume and surface forces acting on a dielectric in an electric field **E**. Electric displacement vector **D**. Gauss's law in presence of a dielectric. Conditions on **D** and **E** at the boundary. Field and potential due to a dielectric sphere in a uniform electric field. Energy density of a dielectric in an external electric field.	**5** **5** **5**
PART- I I	**Mathematical Methods II (35)** **1.** Complex numbers. Polar form. Argand diagram. Geometrical interpretation of algebraic operations on complex numbers. Functions of a complex variable. Single- and multivalued functions. Analytic functions. Cauchy-Riemann equations. **2.** Complex line integrals. Cauchy's integral theorem (no proof is required) for simply connected regions. Simple consequences of Cauchy's theorem. Cauchy's integral formula. Jordan's Lemma. The Taylor and Laurent expansions (statement only). Singular points. Removable singularity. Poles. Essential singularity. **3.** Residue at a pole of order *m*. Cauchy's residue theorem. Evaluation of	**8** **8**

	simple integrals with the help of residue theorem. 4. Linear vector spaces. Examples. Linearly independent set of vectors. Basis and dimensionality of a vector space. Scalar product. Orthogonality of vectors. Linear transformation. Linear operators. 5. Matrix algebra. Transpose of a matrix. Hermitian, orthogonal and unitary matrices. Matrix for rotation in two and three dimensions. The inverse of a matrix. Solution of a system of linear equations by matrix method. Eigenvalues and eigenvectors of a matrix. Properties of eigenvectors and eigenvalues of Hermitian and unitary matrices. Matrix representations of Linear operators. Similarity transformation.	**4** **5** **10**
PART- III	**Statistical Physics (40)** **1.** Probality Theory : Probability of occurrence of event., theorem and total probability and compound probability. Binomial, Poission and Guassian distribution, mean value, variance and standard deviation. **2.** Aim and scope of statistical mechanics. Phase space. μ-space and Γ-space. Phase trajectory. Ensembles. Time average and ensemble average. Principle of equal a priori probability. Microstates and macrostates. Statistical equilibrium. Microcanonical ensemble. Statistical definition of entropy. Entropy of a perfect gas. Sackur-Tetrode formula. Gibbs paradox. Law of equipartition of energy. Application to specific heat. Rotational specific heat of hydrogen. Ortho and para hydrogen. Brief discussion on vibrational specific heat of diatomic molecules. **3.** Quantum statistics. Quantization of phase space. Indistinguishability of identical particles. Symmetry of wavefunction of a system of identical particles. Connection with spin of the particles. Bosons and fermions. Effect of symmetry on counting. Examples illustrating counting procedure for MB, BE, and FD statistics. Derivation of distribution functions for the three statistics. Conditions under which BE and FD distributions reduce to MB distribution. Thermodynamic behaviour of an ideal Bose gas. BE condensation. Einstein and Debye's theories of the specific heat of solids. **4.** Classical theory of black body radiation. Kirchhoff's law. Stefan's law. Wien's displacement law. Rayleigh-Jeans formula for the spectral distribution of the energy of black body radiation. Equation of state of radiant energy. Cavity radiation as a photon gas. Density of states of photons. Derivation of Planck's law by applying BE statistics. Energy density as functions of wavelength and frequency. Low and high frequency limits. Stefan's constant. Entropy of a photon gas. Radiation pressure. **5.** FD distribution function. Chemical potential and Fermi energy. Null-point	**5** **8** **10** **8**

	energy and pressure. Degenerate and nondegenerate Fermi gas. Free electron gas in metals. Density of states. Specific heat of electron gas in metals. Thermionic emission. Richardson-Dushman equation. **6.** One-dimensional random walk. Brownian motion. Langevin and Einstein's theories. Brownian motion of small spherical particles suspended in a viscous liquid. Experimental determination of Avogadro's number by Perrin's method.	**6** **3**
	Atomic and Molecular Physics (21): 1. Measurement of the charge of electron by Millikan's oil drop method and the (e/m) ratio of electrons by Thomson method. Brief outline of Millikan's oil drop method. Photoelectric effect. Characteristic features of the photoelectric phenomenon. Failure of the classical wave theory in explaining these features. Einstein's quantum theory of the photoelectric effect. Stopping potential and determination of h. The concept of photon. Interaction of photons with free and bound electrons. Compton effect. 2. One-electron atoms. Orbital angular momentum and magnetic moment of an electron moving in a Bohr orbit. Bohr magneton. Orbital g-factor. Stern – Gerlach experiment. Electron spin. Spin angular momentum. The quantum numbers S and M_s. Spin magnetic moment and spin g-factor. Toatal angular momentum $\mathbf{J} = \mathbf{L} + \mathbf{S}$. Allowed values of $\mathbf{J}_2$ and J_z. Vector atom model. Fine structure. Elementary theory of spin-orbit coupling and the spin orbitinteraction energy. Spectra of atoms of alkali metals. Doublet structure. Quantum defect and itsdependence on *l*. Principal, sharp, diffuse and fundamental series. Doublet structure. Atomic transitions and selection rules (qualitative discussion). Atom in a magnetic field. Lande's g-factor. Weak-field Zeeman effect Normal and anomalous Zeeman effects, Paschen back effect. 3. Many –electron atoms. Pauli exclusion principle. Shells and subshells in atoms. LS & JJ coupling schemes. Hund's rules. Ground states of atoms. 4. The covalent bond. Hydrogen molecule. Molecular spectra. Rotational, vibrational, and electronic spectra. Rotational and vibrational energy levels of diatomic molecules, Raman effect and its uses.	**5** **10** **3** **3**

COURSE MODULE FOR B.Sc PHYSICS HONOURS STUDENTS

DR. OINDRILA MONDAL

<table>
<tr><th>YEAR</th><th>TOPICS</th><th>NO OF LECTURES</th></tr>
<tr><td rowspan="5">PART- I</td><td>General Properties of Matter (25)
1. Introduction, Stress and strain. Hooke's law. Different elastic moduli. Strain-energy associated with tensile, volume and shearing strain. Theorem on shear. Interrelationship of different elastic moduli. Torsion of a wire. Torsional oscillations. Bending moment. Stresses induced by bending. The cantilever. Beam supported at its two ends and carrying a load at any point of the beam. Flat spiral spring.</td><td>08</td></tr>
<tr><td>2. Introduction. Viscosity. Newtonian and Non-Newtonian fluids. Streamlines. Streamline and Turbulent flow. Critical velocity. Viscous flow through a capillary tube. Reynold's number. Poiseuille's formula. Modification of the formula in the case of gases. Stokes' law and its derivation using dimensional analysis. Terminal velocity of sphere through a viscous liquid. Motion of a body through a viscous liquid. Effect of temperature on viscosity. Principle of the rotating cylinder method for the determination of the coefficient of viscosity of a liquid.</td><td>07</td></tr>
<tr><td>3. Introduction. Molecular origin. Surface energy. Relation between total surface energy and surface tension. Excess pressure on a curved liquid surface. Soap bubble. Shape of liquid drops. Angle of contact. Solid, Liquid and gas in contact. Capillary rise. Surface tension and evaporation. Vapour pressure over a curved surface. Variation of surface tension with temperature.</td><td>07</td></tr>
<tr><td>4. Basic techniques for the production and the measurement of high vacuum. Principles of rotary and diffusion pumps. Pirani and ionization gauges.</td><td>03</td></tr>
<tr><td>Mechanics I (5)
1. Motion of ideal fluids. Stream line and streamline flow. The continuity equation. Euler's equation of incompressible fluid. Steady flow. Bernoulli's theorem and its applications. Toricelli's expression for velocity of efflux of a liquid. Venturimeter.</td><td>05</td></tr>
</table>

	Electrostatics (10) **2.** Conservation of charge. Point charge. Coulomb's law. Superposition principle. Electric field and the corresponding scalar potential. Field and potential due to (a) single point charge (b) uniform linear, planar, and spherical charge distributions. Lines of force. Flux of electric field. Gauss's theorem in integral and differential forms. Simple applications of Gauss's theorem. Laplace's equation. Uniqueness of its solution. Solution of Laplace's equation for simple geometries (two infinite parallel surfaces: coaxial cylindrical surfaces maintained at different potentials). Poisson's equation. Application to sphere with uniform charge density.	**10**
PART- I I	**Electromagnetics (32)** **3.** Magnetic moment. Magnetization M. Magnetic field intensity H. Permeability and magnetic susceptibility. Dia-, para-, and ferromagnetism (brief elementary treatment). Hysterisis. B-H curve. Energy density in a magnetic field. Conditions on B and H at the boundary between two media 4. Generalization of Ampere's law. Displacement current. Maxwell's equations in differential and integral forms. Empirical basis of the equations. Maxwell's equations in material media. Boundary conditions. Vector and scalar potentials. Coulomb and Lorentz gauges. Field energy and field momentum. Poynting's theorem. Poynting vector. (8L) 5. Plane electromagnetic waves in isotropic dielectric media. Energy and momentum of electromagnetic waves. Intensity. Plane waves in conducting media. Skin effect. Reflection at a conducting surface. Polarization of electromagnetic waves. Reflection and refraction of plane waves at a plane interface between dielectrics. Fresnel's relations. Polarization by reflection. Brewster angle. **6.** Scattering of radiation by a free charge. Thomson scattering cross-section (the formula for the time average of the power radiated per unit solid angle by a charged particle may be assumed). Scattering by a bound charge (assume the damping term). Rayleigh scattering cross-section. Blue of the sky. Elementary treatment of normal and anomalous dispersion. Cauchy's formula.	**6** **8** **10** **8**

	Mechanics II (20) **1.** Constraints and their classification. Constraint forces. Work done by the constraint forces. Degrees of freedom. Generalized coordinates. Configuration space. Generalized velocity. Infinitesimal virtual displacement. Principle of virtual work. Critical appraisal of the Newtonian formulation of mechanics. **2.** Infinitesimal virtual displacement. Principle of virtual work. D'Alembert's principle. Reversed effective force. Elimination of forces of constraint. Simple applications of D'Alembert's principle. **3.** Legendre's dual transformation to the Lagrangian of a system. Hamilton's function and Hamilton's equations of motion. Properties of the Hamiltonian. Hamilton's equations of motion for holonomic systems from variational principle. Application of Hamiltonian formalism to simple systems. Nother's Theorem and its significance.	**05** **05** **10**
PART- III	**Solid State Physics (30)** **1.** Crystalline and amorphous solids. Periodic arrangement of atoms. Translational symmetry. Elementary ideas of point symmetry operations. Lattice and basis. Primitive cell. Unit cell. The characteristics (volume of conventional cell, lattice points per cell, number of nearest neighbours, nearest neighbour distance, number of second neighbours, packing fraction) of the three cubic lattices sc, bcc, and fcc. Miller indices. Directions in a crystal. Interplanar distance. Reciprocal lattice. The volume of a primitive cell of reciprocal lattice. The reciprocal lattices of sc and square lattices. Determination of crystal structure by x-ray diffraction. Laue and Bragg equations. Geometrical interpretation of the Bragg equation in the reciprocal space. Ewald construction. The powder method. **2.** Different types of interatomic binding in solids. Ionic crystals. Electrostatic energy. Madelung constant. Repulsive interaction. Cohesive energy of ionic crystals with exponential repulsive interaction. Dielectric materials. Polarization. Lorentz local field. Clausius-Mosotti relation. Induced and orientational polarization. Dipolar polarizability. Langevan's theory of orientational polarizability. 3. Difficulties with the classical free electron theory of metals. Sommerfeld's free electron theory. Free electron gas in three dimensions. Fermi energy, temperature, velocity and momentum. Electrical and thermal conductivity in free electron model. Wiedemann-Franz law and its range of validity. Hall effect. Hall coefficient for one and two types of carriers. Origin of energy bands in solids. Band picture of metals, insulators and semiconductors.	**10** **5** **8**

	4. Dia-, para-, and ferromagnetism. Langevin's formula for molar diamagnetic susceptibility. Elementary quantum theory of paramagnetism. Curie's law. Curie constant. Effective number of Bohr magnetons. Gouy method for the measurement of susceptibility. Ferromagnetism. Spontaneous magnetization. Curie-Weiss law. Weiss molecular field. Weiss's phenomenological theory of ferromagnetism. Ferromagnetic domains. Boundary displacement. Rotation of domains. Hysterisis.	**7**
	Atomic Physics (9) **1.** Critical review of Bohr's theory of hydrogenic spectra. Correction for finite nuclear mass. Singly ionized helium, positronium, and muonic atom. Wilson-Sommerfeld quantization rule. Application to linear harmonic oscillator, particle in a one-dimensional box. The correspondence principle. Failures of old quantum theory. Franck- Hertz experiment, Excitation and Ionisation potentials, metastable states; Bremstrahlung. X –ray spectra, Continous and Characterstic X ray spectra. Production of characteristic x-ray spectra. X-ray transitions without fine structure. Regularity of x-ray line spectra. Moseley's law.	**9**