

**ST. ALOYSIUS COLLEGE, JABALPUR**  
**SYLLABUS PRESCRIBED FOR THE EXAMINATION FOR THE**  
**DEGREE OF MASTER OF SCIENCE IN PHYSICS**  
**(FIRST AND SECOND SEMESTERS) 2016-2017**  
**UNDER SEMESTER SYSTEM**

**SCHEME OF EXAMINATION**

**Semester - I**

<b>Paper</b>	<b>Paper Title</b>	<b>Max. Marks</b>
I	Mathematical Physics	35+15 (CCE) = 50
II	Classical Mechanics	35+15 (CCE) = 50
III	Electronic Devices	35+15 (CCE) = 50
IV	Computational Methods & Programming	35+15 (CCE) = 50
Lab A		50
Lab B		50

**Total – 300**

**Semester - II**

<b>Paper</b>	<b>Paper Title</b>	<b>Max. Marks</b>
I	Quantum Mechanics - I	35+15 (CCE) = 50
II	Statistical Mechanics	35+15 (CCE) = 50
III	Electrodynamics & Plasma Physics	35+15 (CCE) = 50
IV	Condensed Matter Physics	35+15 (CCE) = 50
Lab A		50
Lab B		50

**Total – 300**

## **M. Sc. I Semester**

### **Paper-I: Mathematical Physics**

#### **Unit -I**

Differential equations: Recursion relation, generating functions and orthogonality of Bessel functions of first and second kind, Hermite, Legendre, Associate Legendre and Laguerre Polynomials. Curvilinear co-ordinate system with specific cases of Cartesian, Cylindrical, and Spherical coordinate systems.

#### **Unit -II**

Integral transforms. Fourier integral. Fourier transform and inverse Fourier transforms. Fourier transform of derivatives. Convolution theorem. Elementary Laplace transforms. Laplace transform of derivatives. Application to a damped harmonic oscillator.

#### **Unit -III**

Green's functions: Non-homogenous boundary value problems, Green's function for one dimensional problems, eigen function expansion of Green's function, Fourier transform. Method of constructing Green's function, Green's function for electrostatic boundary value. Problems and quantum-mechanical scattering problem.

#### **Unit -IV**

Complex variables: Analyticity of complex functions. Cauchy Riemann equations. Cauchy theorem. Cauchy integral formula. Taylors, Maclaurin, Laurent series & mapping. Theorem of residues. Simple cases of contour integration. Jordan's lemma Integrals involving multiple valued functions(Branch points).

#### **Unit - V**

This unit will have questions covering all the four units. In addition to the problems given below the unit will consist of problems given in Text / Reference books.

1. Green's function for a linear oscillator, Green's function and the Dirac  $\delta$ -function, finding Green's function for Linear operators in 1-D.
2. Potential due to discrete or continuous charge distribution; vibration of a circular membrane, solving the 1-D harmonic oscillator Schrodinger equation; Relation of the hydrogen atom, Schrodinger equation with Laguerre equation and solution.
3. Solution of initial value problems by using Laplace transform; LT and inverse LT of various functions,
4. Solution of limit dept problems by Fourier transform; FT of Gaussian function, Application of FT of Dirac delta function.
5. Verification of analyticity of simple function, Evaluation of some definite integral using residues etc.
6. Evaluation of integrals in complex variables

### **Text and Reference Books**

- Mathematical Methods for Physicists : G. Arfken
- Matrices and Tensors for Physicists : A.W. Joshi
- Advanced Engineering Mathematical : E. Kreyszig
- Special functions : E.D. Rainville
- Special functions : W.W. Bell
- Mathematical Methods for Physicists and Engineers : K.F. Reily, M.P.Hob Son and S.J. Bence
- Mathematics for Physicist : Mary L Boas

## **M. Sc. I Semester**

### **Paper-II: Classical Mechanics**

#### **Unit - I**

Newtonian mechanics of one and many particles systems: Conservation laws, Constrains their classification, Principle of virtual work; D’Almbert’s principle in generalized coordinates, The Lagrange’s equation from D’Almbert’s principle. Configuration space, Hamilton’s principle deduction from D’Almbert’s principle, Generalized momenta and Lagrangian formulation of the conservation theorems, Reduction to the equivalent one body problem; the equation of motion and first integrals, the differential equation for the orbit.

#### **Unit - II**

The equations of canonical transformation and generating functions; The Hamilton- Jacobi Action and Angel variables. Poisson’s brackets; simple algebraic properties of Poisson.s brackets. The equation of motion in Poisson’s Brackets notation. Poisson theorem; principle of least action. The Kepler problem, Inverse central force field, Rutherford scattering.

#### **Unit - III**

Theory of small oscillations, Equations of motion, Eigen frequencies and general motion, normal modes and coordinates, Applications to coupled pendulum and linear bistable molecule. Rotating coordinate systems. Acceleration in rotating frames. Coriolis force and its terrestrial astronomical applications, Elementary treatment of Eulerian coordinates and transformation matrices. Angular momentum inertia tensor. Euler equations of motion for a rigid body. Torque free motion for a rigid body.

#### **Unit - IV**

Symmetries of space and time. Invariance under Galilian transformation, Covariant four dimensional formulation, 4 -Vectors and 4 - scalars. Relativistic generalization of Newton’s laws, 4 - momentum and 4 - force, variance under Lorentz transformation relativistic mechanics. Covariant Lagrangian, covariant Hamiltonian, Examples.

## Unit - V

This unit will have questions covering all the four units. In addition to the problems given below the unit will consist of problems given in Text / Reference books.

- (1) Simple pendulum with rigid support. Two connected masses with string passing over a pulley, virtual work.
- (2) Various Poisson's brackets thin relation with PBs in quantum mechanics stability of orbits under central force' orbital elements of planetary orbits.
- (3) Rotating frames, small oscillations in Linear triatomic molecule and coupled pendulum.
- (4) 4-momentum and 4-force, Relativistic Kinetic energy, mass variation,

The problems given in this Text and preference books will form tutorial course.

### TEXT AND REFERENCES BOOKS

- Classical Mechanics : N. C. Rana and P.S. Jog (Tata Mc Graw Hill, 1991)
- Classical Mechanics : H. Goldstein (Addision Wesley, 1980)
- Mechanics : A Sommerfiels (Academi Press 1952)
- Introduction to Dynamics : I. Perceival & Richards (Cambridge Univ. Press, 1982)

## M. Sc. I Semester

### Paper-III: Digital Electronics & Electronic Devices

#### Unit – I

**Digital Electronics:** Number systems (decimal, Binary, Octal, hexadecimal) and their conversion, Logic Gates: AND, OR, NOT, NAND, NOR, EX-OR (Truth table, Boolean expression, symbol), diode and transistor as logic gate, laws of Boolean algebra, K-map, De Morgan's theorem.

**Bistable Circuits:** RS Flip-flop, clocked RS Flip flop, Edge trigger Flip flop, D Flip flop Preset and clear.

#### Unit – II

**Operational Amplifiers:** DC Amplifier, Difference amplifier, Op-Amp symbol, OP-AMP Parameters: Input bias current, Input offset current, Input offset voltage, Open loop gain, CMRR, Slew Rate, Concept of virtual ground, summing point, ideal Op-Amp.

**Application of Op-Amp:** Inverting and Non-Inverting modes of Op-Amp, Use of OPAMP as adder, subtractor, differentiator, integrator, IC 741 as Op-Amp.

#### Unit – III

**Transistors:** Junction Field Effect Transistor (JFET); Physical Structure, Principles of Operation, Metal Oxide Semiconductor Field Effect Transistor (MOSFET); Physical Structure, Electronics Mechanism, Mode of Operation, and Metal-Semiconductor Field-Effect-Transistors (MESFET); Physical Structure, Principles of Operation, derivations of the equations for I-V characteristics under different condition.

**Microwave devices:** Tunnel diode, Transfer electron devices (Gunn diode), Avalanche transit time devices, Impatt diodes and Parametric devices.

#### Unit - IV

**Photonic devices:** Radiative and non-radiative transitions, Photo Conductive Devices (LDR), Diode Photo Detectors, Solar cell (open circuit voltage and short circuit current, fill factor), LED (structure, high frequency limit, Working, operation of LED, Applications), Diode lasers (Construction, Population Inversion, Optical Gain, Working and Application) .

### **Unit - V**

This unit will have questions covering all the four units. In addition to the problems given below the unit will consist of problems given in Text / Reference books.

1. Half adder and Full adder; its design, working, truth table.
2. JK Flip Flop and JKMS Flip Flop; its design, working, truth table.
3. Application of Op-Amp as a Function generator.
4. Application of Op-Amp as a Regenerative Comparator (Schmitt Trigger).
5. Design of MOSFET amplification in different configurations.
6. Microwave oscillators: Klystron and Magnetron.
7. Deviation of the condition of lasing action in a two level system, optical pumping.
8. Derivation of rate equation for three – Laval Devices system.

The problems given in this Text and preference books will form tutorial course.

#### **Text and reference books:**

1. Semi Conductor Devices – Physics and Technology : SM Sze (Wiley)
2. Introduction to Semiconductor devices : M.S. Tyagi (John Wiley and Sons)
3. Optical Electronics :AjoyGhatak and K. Thygarajan (Cambridge Univ. Press.).
4. Digital and Analogue Technique: G.N.Navneetha, V.M.Gokhale, R.G.Kale (Kitab Mahal)
5. Electronic Devices and Circuit Theory; Robert L. Boylestad, Louis Nashelsky (Pearson)
6. Microwave Devices and Circuits: Samuel Y. Liao (Pearson)
7. Electronic Devices and Circuit Theory; Louis Nashelsky and Robert Boylestad (Pearson Education).
8. Electronic Devices and Integrated Circuits: Singh, B. P., Singh, Rekha (Pearson Education).
9. Op-Amps and Linear Integrated Circuits: Ramakant A. Gayakwad (Prentice Hall)

## M. Sc. I Semester

### Paper-IV: Computational Methods and programming

#### Unit – 1

**Introduction to C:** Data type (int, float, double, char, long, long double etc.) operators (Unary, Binary and ternary), input /output statement (scanf(), printf()), control statements (if, for, while, do while, switch -case-default), Function (type of Function, function definition, function calling, formal arguments, actual arguments, function prototype), Program structure, string (Array, character array), string manipulation functions like strlen(), strcpy(), strcat(), strcmp(), etc.

#### Unit – 2

**Method for determination of zeros:** linear and non-linear algebraic equation and transcendental equations using bisection method, false position method and Newton Raphson method, convergence of solutions, solutions of simultaneous linear equation, Gaussian elimination method, pivoting, iterative method, Matrix inversion.

#### Unit – 3

**Eigen Value and Eigen Vectors of Matrices:** Power and Jacobi method, finite difference interpolation with equally and unequally spread points, curve fitting, polynomial least squares and cubic spline fittings. Numerical differentiation and Integration, Newton-Cotes Formulae, error estimates, Gauss-Method.

#### Unit – 4

**Interpolation:** Lagrange's Interpolation, Finite difference and operators, Newton forward, Newton backward, Gauss forward, Gauss backward, Stirling's interpolation divided difference formula.

#### Unit – 5

**Numerical solution of ordinary differential equation :** Euler and Runge-Kutta Methods, predictors and corrector method. Introduction to partial differential equations & their classification. Solution of Laplace Equation by Finite Difference Method. Random variables, Monte Carlo evaluation of integrals

#### **Suggested Readings:**

1. Introduction method of numerical analysis: Sastry
2. Numerical Analysis : Rajaraman
3. Programming with C : Gottfried
4. Programming with C : Balaguruswamy
5. Numerical Analysis : Balaguruswamy



## **M. Sc. II Semester**

### **Paper-I: Quantum Mechanics-I**

#### **Unit - I**

Basic Postulates of quantum Mechanics, equation of continuity, Normality, orthogonality and closure properties of eigen functions, expectation values and Ehrenfest theorems, solution of Schrödinger equation for one dimensional (a) potential well (b) potential step and (c) Potential barrier.

#### **Unit - II**

Linear vector space, concept of Hilbert space, bra and ket notation for state vector, representation of state vectors and dynamical variables by matrices and unitary transformation (Translation and rotation), creation and annihilation operators, matrices for  $x$  and  $p$ . Heisenberg uncertainty relation through operators (Schwartz inequality).

#### **Unit -III**

Solution of Schrödinger equation for (a) linear harmonic oscillator (b) hydrogen - like atom (c) square well potential and their respective application to atomic spectra, molecular spectra and low energy nuclear states (deuteron).

#### **Unit - IV**

Angular momentum in quantum mechanics, Eigen values and Eigen function of  $L^2$  and  $L_z$  in term of spherical harmonics, commutation relation.

Identical particles with spin, symmetric and antisymmetric wave functions, Pauli's exclusion principle, Pauli's spin matrices, Slater determinant.

## Unit - V

This unit will have questions covering all the four units. In addition to the problems given below the unit will consist of problems given in Text / Reference books.

- (1) Plotting of Harmonic oscillator wave functions in 1-d.
- (2) Energy levels of a particle of mass  $m$  moving in one-dimensional potential.

$$V(x) = \begin{cases} +\infty & x < 0 \\ +\frac{1}{2} m\omega^2 x^2 & x > 0 \end{cases}$$

- (3) Wave function corresponding to minimum uncertainty product. Gaussian wave packet. Spread of wave packet in time.
- (4) Continuous basis corresponding to position eigen values and wave functions corresponding to state vectors using position and momentum representation.
- (5) Rotational spectra of diatomic molecules.
- (6) Vibrational and rotational spectra of diatomic molecules.
- (7) Spin and statistics

### Books Recommended

1. L I Schiff, Quantum Mechanics
2. S Gasiorovvicz, Quantum Physics
3. B Craseman and J D Powell Quantum Mechanics
4. A P Messiah Quantum Mechanics
5. J. J. Sakurai Modern Quantum Mechanics
6. Mathews and Venkatesan Quantum Mechanics

## **M. Sc. II Semester**

### **Paper-II: Statistical Mechanics**

#### **Unit - I**

Foundation of statistical mechanics, specification of states of a system contact between statistics and thermodynamics, classical ideal gas entropy of mixing and Gibb's paradox. Microcanonical ensemble, phase space, trajectories and density of states, Liouville theorem, canonical and grand canonical ensembles, partition function, calculation of statistical quantities, energy and density fluctuations.

#### **Unit-II**

Statistics of ensembles, statistics of indistinguishable particles, density matrix, Maxwell Boltzmann, Fermi Dirac and Bose- Einstein statistics, properties of ideal Bose gases, Bose Einstein condensation, properties of ideal Fermi gas, electron gas in metals, Boltzman transport equation.

#### **Unit-III**

Cluster expansion for a classical gas, virial equation of state, mean field theory of Ising model in 3, 2 and 1 dimension. Exact solution in one-dimension.

#### **Unit - IV**

Thermodynamics fluctuation spatial correlation Brownian motion, Langevin theory, fluctuation dissipation theorem, the Fokker-Planck equation, Onsager reciprocity relations

#### **Unit - V**

This unit will have questions covering all the four units. In addition to the problems given below the unit will consist of problems given in Text / Reference books.

- (1) Calculation of number of states and density of states.
- (2) Relative population of particles in two energy levels.
- (3) Liquid helium II

- (4) Electrical and thermal conductivities.
- (5) Evaluation of virial coefficient
- (6) Critical indices.
- (7) Applications of Onsager relation
- (8) Diffusion co-efficient

### **Books Recommended**

- 1. F Reif Statistical and thermal Physics
- 2. K Huang Statistical Mechanics
- 3. R K Pathria Statistical Mechanics
- 4. R Kubo Statistical Mechanics
- 5. Tandan Statistical Physics

## **M. Sc. II Semester**

### **Paper-III: Electrodynamics & Plasma Physics**

#### **Unit - I**

Review of Basics of electrostatics and magnetostatics, electric field, Gauss's law, Laplace and Poisson equations, method of images, Biot-Savart law, Ampere law, Maxwell's equations, scalar and vector potentials, gauge transformation, Lorentz gauge, Coulomb Gauge, Solution of Maxwell equations in conducting media radiations by moving charges, retarded potentials, Lienard-wiechert potentials, fields of charged particles in uniform motion, fields of arbitrarily moving charge particle.

#### **Unit-II**

Fields of an accelerated charged particles at low velocity and high velocity, angular distribution of power radiated, Review of four vector and Lorentz transformation in 4-dimensional spaces, Invariance of electric charge, relativistic transformation properties of E and H fields. Electromagnetic fields tensor in 4- dimensional Maxwell equation, Four Vector current and potential and their invariance under Lorentz transformation, covariance of electrodynamics. Lagrangian and Hamiltonian for a relativistic charged particle in External EM field; motion of charged particles in electromagnetic fields, uniform and nonuniform E and B fields.

#### **Unit -III**

Elementary concept of occurrence of plasma. Gaseous and solid state plasma. Production of gaseous and solid state plasma. Plasma parameters. Plasma confinement pinch effect instability in a pinched- plasma column. Electrical neutrality in a plasma. Debye screening distance. Plasma oscillations: Transverse oscillations and longitudinal oscillations.

#### **Unit - IV**

Domain of Magnetohydrodynamics and plasma Physics : Magnetohydrodynamic equations, magnetic hydro-static pressure hydrodynamic waves: Magneto-sonic and Alfvén waves, particle orbits and drift motion in a plasmas, Experimental study of Plasma, the theory of single and double probes.

## Unit - V

This unit will have questions covering all the four units. In addition to the problems given below the unit will consist of problems given in Text / Reference books.

- (1) Obtain the formal solution for electromagnetic boundary value problem with Green function.
- (2) Discuss the problem of conducting sphere in a uniform electric field by method of images and Green's functions.
- (3) For a solenoid wound with  $N$  turns per unit length and carrying a current  $I$ , show that the magnetic flux density on a point on the axis is given (for  $N \rightarrow \infty$ ) by

$$B_z = \frac{2\pi NI}{C} (\cos \theta_1 + \cos \theta_2)$$

Where  $\theta_1, \theta_2$  are the angles between the axis and the lines joining the point on the axis to the first and last turns of the solenoid.

- (4) A linear accelerator accelerates protons to almost relativistic speeds. Determine fraction of power radiated by the protons to the power supplied in terms of the gradients of the linear electric field.
- (5) A charged particle oscillated according to the harmonic law. Determine the total average intensity of the emitted radiation.
- (6) Discuss the Lagrangian and Hamiltonian for a relativistic charged particle in External electromagnetic field.
- (7) Obtain the expression for energy radiated as Cherenkov radiation per unit distance along the path of the particle.
- (8) Consider a magnetic field configuration that is cylindrically symmetric and a charged particle is injected into it. Use the adiabatic invariant of motion to describe conditions in which the injected particle would bounce back from the direction of increasing field gradient.
- (9) Consider the problem of waves in an electronic plasma when an external magnetic field  $B_0$  is present. Use the fluid model, neglecting the pressure term as well as collisions.
  - (a) Write down the linearized equations of motion and Maxwell equations, assuming all variables vary as  $\exp(ik \cdot x - i\omega t)$ .
  - (b) Show that the dispersion relation for the frequencies of the different modes in terms of the wave number can be written.
 
$$\omega^2(\omega^2 - \omega_p^2)(\omega^2 - \omega_p^2 - k^2 c^2) = \omega_B^2(\omega^2 - k^2 c^2) [\omega^2(\omega^2 - \omega_p^2 - k^2 c^2) + \omega_p^2 c^2 (k \cdot b)^2]$$

where  $b$  is the unit vector in the direction of  $B$ ,  $\omega_p$  and  $\omega_B$  are the plasma and precession frequencies, respectively.
  - (c) Show that for propagation parallel to  $B_0$  the dielectric constant is recovered.
  - (d) Assuming  $\omega_B \ll \omega_p$ , solve approximately for the various roots for the cases
    - (i)  $K$  parallel to  $b$
    - (ii)  $K$  perpendicular to  $b$ . Sketch your result for  $w^2$  versus  $k^2$  in the two cases.

## **Books Recommended**

1. Bitteneerort Plasma Physics
2. Chen Plasma Physics
3. Gupta, Kumar, Singh Electrodynamics
4. Sen Plasma state and matter
5. Jackson Classical electrodynamics
6. Pamolsky & Philips Classical electricity and Magnetism

## **M. Sc. II Semester**

### **Paper-IV: Condensed Matter Physics**

#### **Unit - I**

Interaction of X-ray with matter, absorption of X-rays, Elastic scattering from a perfect lattice. The reciprocal lattice and its application to diffraction techniques, the Laue, powder and rotating crystal methods. Crystal structure factor and intensity diffraction maxima. Extinction due to lattice centering.

Point defects, line defects and planar (stacking) faults. The role of dislocation in plastic deformation and crystal growth. The observation of imperfections in crystals. X-ray and electron microscopic techniques

#### **Unit - II**

Free electron Fermi gas, Energy levels of orbital in one and three dimensions. Electrons in a periodic lattice. Bloch theorem, band theory of solids, Classification of solids effective mass. Tight binding, cellular and pseudopotential methods. Fermi surface. De Haas von Alfen effect, Super conductivity, critical temperature persistent current. Meissner effect, general idea about high temperature superconductors.

#### **Unit-III**

Atomic and molecular Polarizability, Clausius-Mossotti relation, types of polarizability, dipolar polarizability and frequency dependence of dipolar polarizability, ionic and electronic polarizability, Hall effect. Quantum Hall Effects, Magnetoresistance.

#### **Unit - IV**

Weiss Theory of Ferromagnetism. Heisenberg model and molecular field theory, spin waves and magnons, Curie-law for susceptibility, ferri and anti-Ferromagnetic order. Domains and Bloch-wall energy.



## Unit - V

This unit will have questions covering all the four units. In addition to the problems given below the unit will consist of problems given in Text / Reference books.

- (1) Given that the primitive basis vectors of a lattice  $a = (a/2)(i + j)$ ,  $b = a/2(j + k)$  and  $c = a/2(k + j)$  where  $i, j$  and  $k$  are usual three unit vectors along cartesian coordinates. What is the Bravais lattice?
- (2) Determine planes in a fcc structure having highest density of atoms.

*Or*

Evaluate density of atoms for Cu. in atoms/cm<sup>2</sup>.

- (3) For the delta function potential and with  $p > 1$  find at  $k = 0$  the energy of the lowest energy band. Also find the band gap at  $k = \pi/a$ .
- (4) Consider a square, lattice in two dimensions with the crystal potential.

$$U(x,y) = .4U \cos(\pi x/a) \cos(\pi y/a)$$

Apply the central equation to find approximately the energy gap at the corner point  $(\pi/a, \pi/a)$  of the Brillouine Zone.

- (5) Explain why the Hall constant is inversely proportional to the electron concentration  $M$ .

### Books Recommended

1. Kittel Solid State Physics
2. Ashcroft & Mermin Solid State Physics
3. L.V. Azaroff Introduction to Solid State Physics
4. Verma & Srivastava Crystallographic Solid State Physics
5. A.J. Dekker Solid State Physics
6. P.M. Chaiken & T.C. Lubensky Principles of Condense Matter Physics