University of Rajasthan
Jaipur

SYLLABUS

M.Sc. PHYSICS

(Annual Scheme)

M.Sc. (Previous) Examination 2024

M.Sc. (Final) Examination 2025

Dy. Registrar
(Academic)
University of Rajasthan
JAIPUR

NOTICE

1. The Ordinance governing the examinations in the Faculties of Arts, Fine Arts, Social Sciences, Science, Commerce and Law are contained in a separate booklet. The students are advised to refer to the same.

2. Changes in Statutes/Ordinances/Rules/Regulations/ Syllabi and Books may, from time to time, be made by amendment or re-making and a candidate shall, except in so far as the University determines otherwise comply with any change that applies to years he has not completed at the time of change.

3. All court cases shall be subject to the jurisdiction of the Rajasthan University head quarter at Jaipur only and not any other place.

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SCHEME OF EXAMINATION

(Annual Scheme)

Each Theory Paper	3 hrs. duration	100 Marks
Dissertation / Thesis/ Survey Report/Field Work, if any.		100 Marks

2. The number of papers and the maximum marks for each paper / Practical shall be shown in the syllabus for the subject concerned. It will be necessary for a candidate to pass in theory part as well as in the Practical part (Wherever prescribed) of a subject/paper separately.

3. A candidate for a pass at each of the Previous and the Final Examination shall be required to obtain (i) atleast 36% marks in the aggregate of all the papers prescribed for the examination and (ii) atleast 36% marks in practical (s) wherever prescribed at the examination, provided that if a candidate fails to secure atleast 25% marks in each individual paper at the examination, and also in the test dissertation/Survey report/Field Work, wherever prescribed, he shall be deemed to have failed at the examination notwithstanding his having obtained the minimum percentage of marks required in the aggregate for that examination. No division will be awarded at the Previous Examination. Division shall be awarded at the end of the Final Examination on the combined marks obtained at the Previous and the Final Examinations taken together, as noted below:

First Division	60%	of the aggregate marks taken together of the Previous and the Final Examinations.
Second Division	48%	

All the rest will be declared to have passed the examination

4. If a candidate Clears any Paper (s) / Practical (s) / Dissertation prescribed at the Previous and/or Final examination after a continuous period of three years, then for the purpose of working out his division the minimum pass marks only viz. 25% (36% in the case of practical) shall be taken into account in respect of such Paper (s) / Practical (s) / Dissertation as are cleared after the expiry of the aforesaid period of three years : provided that in case where a candidate requires more than 25% marks in order to reach the minimum aggregate as many marks out of those actually secure by him will be taken into account as would enable him to make up the deficiency in the requisite minimum aggregate.

5. The Thesis/ Dissertation/ Survey Report/ Field Work shall typewritten and submitted in triplicate so as to reach the office of the Registrar atleast 3 weeks before the commencement of the theory examination. Only such candidates shall be permitted to offer Dissertation/ Field Work/ Survey Report/ Thesis (If provided in the scheme of Examination) in lieu of a paper as have secured atleast 55% marks in the aggregate of all the paper prescribed for the previous examination in the case of annual scheme irrespective of the number of paper in which a candidate actually appeared at the examination.

N.B.—Non-Collegiate candidates are not eligible to offer dissertation as per provisions of O.170-A.

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M. Sc PHYSICS PREVIOUS

Paper-I	:	Classical Mechanics and Mathematical Method in Physics	Max. Marks 100 Time 3 hrs.
Paper-II	:	Classical Electrodynamics	Max. Marks 100 Time 3 hrs.
Paper-III	:	Quantum Mechanics, Atomic and Molecular Physics	Max. Marks 100 Time 3 hrs.
Paper-IV	:	Electronics, Numerical Methods and Computer Programming	Max. Marks 100 Time 3 hrs.

PAPER - I : CLASSICAL MECHANICS AND MATHEMATICAL METHODS IN PHYSICS

Max. Marks 100 Duration 3 hrs.

Note : In all Ten questions are to be set, Five from each section. Candidates are required to attempt five questions in all, taking at least two questions from each section.

Section A

1. Holonomic and nonholonomic constraints: D-Alembert's Principle. Generalized coordinates, Lagrangian, lagrange's equation and its applications. Velocity dependant potential in Lagaragian formulation. Generalized momentum, Legendre transformation, Hamiltonian, Hamilton's Canonical equation.

2. Calculus of variations and its application to simple problems. Hamilton's variational principle, Derivation of Lagrange's and Hamilton. Canonical equation from Hamilton's variational principle. Extension of Hamilton's Principle for nonconservative and nonholonomic systems, Method of Lagrange's multipliers. Conservation Principle and Noether's theorem. Conservation of energy, linear momentum and angular momentum as a consequence of homogeneity of time and scope and isotropy of space respectively.

3. Canonical transformation, integral in variants of poincare Lagrange's and Poisson brackets as canonical invariants. Equation of motion in Poisson bracket formulation, Infinitesimal contact transformation and generators of Symmetry, Liouville's theorem, Hamilton Jacobi equation and its applications.

4. Action angle, variable adiabatic invariance of action variable : The Kepler problem in action angle variables, [illegible]

Section B

5. Coordinate transformation in N-dimesional space: Contravriant and covariant tensor, Jacobian. Relative tensor, pseudo tensors (Example: change density, angular momentum) Algebra of tensors, Metric tensor, Associated tensors, Reimannian space (Example : Euclidean space and 4-D Minkowski space). Christoffel symbols, transformation of Christoffel symbols. Covariant differentiation. Ricci's theorem. Divergence. Curl and Laplacian in tensor form. Stress and Strain tensors. Hook's law in tensor form. Lorentz Covariance of Maxwell equation. Klein-Gordon and Dirac equation. Test of covariance of Schrodinger equation.

6. Group of transformations. (Example : symmetry transformation of square . Generators of a finite group. Normal subgroup, Direct product of groups. Isomorphism and Homomorphism. Representation theory of finite groups. Invariant subspace and reducible representations, irreducible representation. Crystallo-graphic point groups. Irreducible representation of C_n. Translation group and the reciprocal lattice.

7. Fourier Transforms : Development of the Fourier integral from the Fourier Series, Fourier and inverse Fourier transforms : Simple applications: Finite wave train. Wave train with gaussian amplitude, Fourier transform of derivatives. solution of wave equation as an application, Convolution theorem, intensity in terms of spectral density for quasi-monochromatic EM waves. Momentum representation. Application to hydrogen atom and harmonic oscillator problems. Application of Fourier transform to diffraction theory : Diffraction pattern of one and two slits.

8. Laplace transforms, and their properties, Laplace transform of derivatives and integrals. derivatives and integral of Laplace transform. Laplace transform of periodic functions, inverse Laplace transform. Convolution theorem. Impulsive Function. Application of Laplace transform in solving linear differential equations with constant coefficient with variable coefficient and linear partial differential equation.

Reference Books:

1. Goldstein—Classical Mechanics.
2. Landau and Lifshitz—Classical Mechanics.
3. A. Raychoudhary—Classical Mechanics.
4. Mathematical Methods for Physicists : George Arkfen (Academic Press).
5. Applied Mathematics for Engineers and Physicists . L. A. Pipe (Mc Graw Hill).
6. Mathematical Methods—Potter and Goldberg (Prentice Hall of India).
7. Elements of Group Theory for Physicists : A. W. Joshi (Wiley Eastern Ltd.)

PEPER - II : CLASSICAL ELECTRODYNAMICS

Max. Marks 100 Duration 3 hrs.

Note : In all Ten questions are to be set. Five from each section. Candidates are required to attempt five questions in all, taking at least two questions from each section.

Section A

1. **Electrostatics:** Electric field. Gauss law, Differential form of Gauss law. Another equation of electrostatics and the scalar potential. surface distribution of charges and dipoles and discontinuties in the electric field and potential, Poisson and Laplace equations. Green's Theorem. Uniqueness of the solution with Dirichlet or Neumann Boundary conditions, Formal solution of Electrostatic Boundary value problem with Green's Function, Electrostatic potential energy and energy density, capacitance.

Boundary-Value Problems in Electrostatics : Methods of Images. Point charge in the presence of a grounded conducting sphere point charge in the presence of a charge insulated conducting sphere. Point charge near a conducting sphere at fixed potential. conducting sphere in a uniform electric field by method of images. Green function for the sphere, General solution for the potential, Conducting sphere with Hemispheres at different potential, orthogonal functions and expansion

2. **Multipoles, Electrostatics of Macroscopic Media Dielectrics:** Multiple expansion, multipole expansion of the energy of a charge distribution in an external field, Elementary treatment of electrostatics with permeable media, Boundary value problems with dielectrics. Molar polarizability, and electric susceptibility. Models for molecular polarizability, Electro-static energy in dielectric media.

3. **Magnetostatics :** Introduction and definition, Biot and Savart law, the differential equation of magnetostatics and Ampere's law, Vector potential and Magnetic induction for a circular current loop, Magnetic fields of a localized current distribution, Magnetic moment, Force and torque on and energy of a localized current distribution in an external magnetic induction, Macroscopic equations. Boundary conditions on B and H. Methods of solving Boundary-value problems in magnetostatics, Uniformly magnetized sphere. Magnetized sphere in an external field, Permanent magnets, Magnetic shielding spherical shell of permeable material in an uniform field.

4. Time ...

Derivation of the equations of Macroscopic Electromagnetism, Poynting's theorem and conservations of energy and momentum for a system of charged particles and EM fields. Conservation laws for macroscopic media. Electromagnetic field tensor. Transformation of four potentials and four currents. Tensor description of Maxwell's equation.

Section B

5. **Plane Electromagnetic Waves and Wave Equation :** Plane wave in a nonconducting medium. Frequency dispersion characteristics of dielectrics, conductors and plasmas, waves in a conducting or dissipative medium, super position of waves in one dimension, group velocity, casualty connection between D and E Kramers-Kroning relation.

6. **Magnetohydrodynamics and Plasma Physics :** Introduction and definitions. MHD equations Magnetic diffusion viscosity and pressure, Pinch effect instabilities in a pinched plasma column. Magnetohydrodynamic waves, Plasma oscillations, short wave length limit of plasma oscillations and Debye shielding distance

7. **Covariant Form of Electrodynamic Equations :** Mathematical properties of the space-time special relativity, Invariance of electric charge invariance of electrodynamics, Transformation of electromagnetic fields.

Radiation by moving charges : Lienard-wiechert Potentials for a point charge. Total power radiated by an accelerated charge : Larmour's formula and its relativistic generalization, Angular distribution of radiation emitted by an accelerated charge, Radiation emitted by a charge in arbitrary extremely relativistic motion. Distribution in frequency and angle of energy radiated by accelerated charges. Thomson scattering and radiation, scattering by quasifree charges, coherent and incoherent scattering, Cherenkov radiation.

8. **Radiation damping, self fields of a particle, scattering and absorption of radiation by a bound system :** Introductory considerations, Radiative reaction force from conservation of energy, Abraham Lorentz evaluation of the self force, difficulties with abraham Lorentz model. Integro-differential equation of motion including radiation damping, Line Breadth and level shift of an oscillator, Scattering and absorption of radiation by an oscillator. Energy transfer to a harmonically bound charge.

Reference Books :

1. J.D. Jackson—Classical Electrodynamics
2. Panofsky and Philips Classical Electricity and Magnetism
3. Introduction to Electrodynamics—Griffiths
4. Landau and Lifshitz — Classical ...

PAPER - III : QUANTUM MECHANICS, ATOMIC AND MOLECULAR PHYSICS

Max. Marks 100 Duration 3 hrs.

Note : In all Ten questions are to be set. Five from each section. Candidates are required to attempt five questions in all, taking at least two questions from each section.

Section A

1. (a) ***States, Amplitudes and Operators:*** States of a quantum mechanical system, representation of quantum - mechanical states, properties of quantum mechanical amplitude, operators and change of state, a complete set of basis states, products of linear operators, language of quantum mechanics, postulates, essential definitions and commutation relations.

1. (b) **Observable and description of system:** Process of measurement, expectation values, time dependence of quantum mechanical amplitude, observables with no classical analogue, spin, dependence of quantum-mechanical amplitude on position, the wave function, super-position of amplitudes, identical particles.

2. **Hamiltonian matrix and the time evolution of Quantum mechanical States :** Hermiticity of the Hamiltonian matrix, Time independent perturbation of an arbitrary system, simple matrix examples of time independent perturbation, energy given states of a two state-system, diagonalizing of energy matrix, time independent perturbation of two state system the perturbative solution: Weak field and strong field cases, general description of two state system. Pauli matrices, Ammonia molecule as an example of two state system.

3. **Transition Between Stationary States:** Transitions in a two state system, time dependent perturbations- The Golden rule, phase space, emission and absorption of radiation, induced dipole transition and spontaneous emission of radiation, energy width of a quasi stationary state.

The Co-ordinate Representation: Compatible observables, quantum conditions and uncertainty relation, Co-ordinate representation of operators, position, momentum and angular momentum, time dependence of expectation values, the Ehrenfest's theorem, the time evolution of wave function, the Schrodinger equation, energy quantization, periodic potential as an example.

4. **Symmetries and Angular momentum : (a) Compatible observables and constants of motion, symmetry transformation and conservation laws, invariance ...**

representations of the angular momentum operators and their eigenstates, co-ordinate representations of the orbital angular momentum operators and their eigen state (spherical harmonics), composition of angular momentum, Clebsch-Gordon coefficients tensor operators and Winger Expart theorem, commutation relations of Jx, Jy, Jz with reduced spherical tensor operator, matrix elements of vector operators, time reversal invariance and vanishing of static electric dipole moment of a stationary state.

Section B

5. **Hydrogen Atom :** Gross structure energy spectrum, probability distribution of radial and angular (ℓ=1, 2) wave functions (no derivation), effect of spin, relativistic correction to energy levels and fine structure, magnetic dipole interaction and hyperfine structure, the Lamb shift (only an qualitative description).

6. **Interaction with External Fields :** Non degenerate first order stationary perturbation method, atom in a weak uniform external electric field and first and second order Stark effect, calculation of the polarizability of the ground state of H-atom and of an isotropic harmonic oscillator, Degenerate stationary perturbation theory. Linear Stark effect for H-atom levels, inclusion of spin-orbit and weak magnetic field, Zeeman effect, strong magnetic field and calculation of interaction energy.

7. **Systems with Identical Particles:** Indistinguishability and exchange symmetry, many particle wave functions and Pauli's exclusion principle, spectroscopic terms for atoms.

The Helium atom. Variational method and its use in the calculation of ground state and excited state energy, Helium atom. The Hydrogen molecule, Heitler-London method for H_2 molecule, WKB method for one dimensional problem, application to bound states (Bohr-Sommerfield quantization) and the barrier penetration (alpha decay, problems.

8. **Spectroscopy (qualitative) :** General features of the spectra of one and two electron system-singlet, doublet and triplet characters of emission spectra, general features of Alkali spectra, rotation and vibration band spectrum of a molecule, PQ and R branches, Raman spectra for rotational and vibrational transitions, comparison with infra red spectra, general features of electronic spectra, Frank and Condon's principle.

Reference Books :

1. Ashok Das and A.C. Melissionos. Quantum Mechanics- A modern Approach (Gordon and Breach Science Publishers).
2. P.A.M. Dirac. Quantum Mechanics.
3. E. Merzbaker. Quantum Mechanics, Second Edition

4. L.P. Landau and E.M. Lifsbitz, Quantum Mechanics-Non relativistic theory (Pergamon Press)
5. A. Ghatak and S. Lokanathan. Quantum Mechanics: Theory and Applications, Third Edition (Mac Millan India Ltd.)
6. G. K. Woodgate, Elementary Atomic Structure, Second Edition Clarendon Press, Oxford.
7. T.A. Littlefield- Atomic and Molecular Physics.
8. Eistanberg and Rasmik- Quantum Physics of Atoms. Molecules, Solids and Nuclear Particles.
9. White - Atomic Spectra.
10. Herzberg - Molecular Spectra.

PAPER - IV : ELECTRONICS, NUMERICAL METHOD AND COMPUTER PROGRAMMING

Max. Marks 100 Duration 3 hrs.

Note :

1. *In all Ten questions are to be set. Five from each section. Candidates are required to attempt five questions in all, taking at least two questions from each section.*
2. *Simple calculator is allowed in the examination hall.*

Section A

1. **Operational Amplifiers :** Differential amplifier - circuit configurations - dual input, balanced output differential amplifier. DC analysis - AC analysis, inverting and non inverting inputs, CMRR - constant current bias level translator.

Block diagram of a typical Op-Amp-analysis. Open loop configuration, inverting and non-inverting amplifiers. Op-amp with negative feedback - voltage series feed back - effect of feed back on closed loop gain, input rersistence, output resistance, bandwidth and output offset voltage - voltage follower.

Practical op-amp-input offset voltage - input bias current - input offset current, total output offset voltage, CMRR frequency response. DC and AC amplifier, summing, scaling and averaging amplifiers, instrumentation amplifier, integrator and differentiator.

2. **Oscillators and Wave Shaping Circuits: Oscillator Principle. Oscillator types, Frequency stability, response. The Phase shift oscillator. Wein bridge Oscillator, LC tunable oscillators, Multivibrators- Monostable and Astable, Comparators, Square wave and Triangle wave generation, Clamping and Clipping**

3. **Digital Electronics** : Combinational Logic : The transistor as a switch circuit Realisation of OR, AND, NOT, NOR and NAND gates, Exclusive OR gate Boolean algebra - Demorgan's theorems Adder, Subtractor, Comperator, Decoder/ Demultiplexer Data selector/multiplexer - Encoder.

Sequential Logic: Flip - Flops : one - bit memory, The RS Flip-flop, JK Flip- Flop, JK master slave Flip - Flops, T Flip - Flop, D Flip - Flop, Shift resisters - synchronous and asynchronous counters- cascade counters, Binary counter, Decade counter.

Basic concepts about fabrication and characteristics of integrated circuits.

4. **Microprocessors :** Introduction to microcomputers : memory - input/output - Interfacing devices 8085, CPU - Architecture - BUS timings - Demultiplexing the address bus generating control signals - Instruction set - addressing modes - Illustrative programmes - writing assembly language programmes looping, counting and indexing - counters and timing delays - stack and subroutine.

Section B

5. **Errors in numerical analysis:** Source of error, Round off error, Computer Arithmetic, Error Analysis, Condition and stability, Approximation, Functional and Error analysis, the method of Undetermined Coefficients.

Use of interpolation formula, Iterated interpolation, Inverse interpolation, Harmite interpolation and Spline interpolation, Solution of Linear equations : Direct and Iterative methods, Calculation of eigen values and eigen vectors for sysmmetric matrices.

6. **Solution of Nonliner equation:** Bisection method, Newton's method, modified Newton's method, method of Iteration, Newton's method and method of iteration for a system of cosuation Newton's method for the case of complex roots.

Integration of a function: Trapezoidal and Simpson's rules. Gaussian quadrature formula, Singular integrals, Double integration.

7. **Integration of Ordinary differential equation :** Predictor - corrector methods, Runga-Kutta method. Simultaneous and Higher order equations.

Numerical Integration and Differentiation of Data, Least-Squares Approximations. Fast Fourier Transform.

Some elementary information about Computer: CPU, Memory, Input Output devices. Super, Mini and Micro systems, MS-DOS operating system, High Level ...

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8. **Fortran 77 :** Variables, Expressions, Jumping, Branching and Looping statements, Input/ Output statement, Statement for handling Input/ Output Files, Subroutine External Function, special statements: COMMON, ENTRY, FORMAT, PAUSE, EQUIVALENCE. Programming of simple problems involving use of interpolation differentiation, integration, matrix inversion and least square analysis.

Reference Books :

1. Ryder—Electronic Fundamentals and applications.
2. Millman and Taub—Pulse, Digital and Switching wave forms.
3. Millman and Helkias—Integrated Electronics.
4. Ryder—network Lines and Fields.
5. Bapat—Electronics Devices and Circuitrs.
6. A Ralston and P. Rabinowitz, A First Course in Numberical analysis Mc Graw Hill (1985)
7. S.S. Sastry, Introductory Methods of Numerical Analysis. Prentice-hall of India (1979).
8. Ram Kumar, Programming with Fortran 77. McGraw-Hill (1986).
9. "Electronic Devices and circuit theory" by Robert Boylested and Louis Nashdsky PHI, New Delhi. 1100 001. 1991
10. "OP Amps & Linear integrated circuits." by Ramakanth A. Gayakwad PHI, Second Edition, 1991.
11. "Digital principles and Applic ions" by A.P. Malvino and Donald P.Leach, Tata Megraw - Hill company, New Delhi, 1993.
12. "Microprocessor Architecture, Programming and applications with 8085/8086 by Ramech S. Gaonkar, Wiley - Eastern Ltd., 1987.

LIST OF EXPERIMENTS FOR M.Sc PREVIOUS

Scheme :

The examination will be conducted for two days, 6 hrs. each day. The distribution of the marks will be as Follows :

	Marks
Two experiments	120
Viva	40
Record	40
Total	**200**
Minimum Pass Marks	**72**

List of Experiments (any eighteen) :

1. **To design a single stage amplifier of a given voltage gain and lower cut of frequencies.**
2. To determine ...

3. To design a RC coupled two stage amplifier of a given gain and the cut off frequencies.
4. To study Hartley oscillator.
5. To Study Transistor bias Stability.
6. To design a Multivibrator of given frequency and study its wave shape
7. To study the characteristics of FET and use it o design an relaxation oscillator and measure its frequency.
8. To study the characteristics of an operational amplifier.
9. To study the characteristics of a UJT and use it to design a relaxation oscillator and measure its frequency.
10. To study the addition, integration and differentiation properties of an operational amplifier.
11. Determine Plack constant using solar Cell.
12. To determine Plack constant and work function by a photo-cell.
13. To study regulated power supply using (A) Zener diode only (b) Zener diode with a series transistor (c) Zener diode with a shunt transistor
14. To verify Fresnel's formula.
15. To study the percentage regulation and variation of Ripple factor, with load for a full wave rectifier.
16. To study analog to digital and digital to analog conversion.
17. To study a driven mechanical oscillator.
18. To verify Hartmann's formula using constant deviation spectrograph.
19. To find e/m of electron using Zeeman effect.
20. To find Dissociation energy to I.
21. Study of CH Bands.
22. Salt Analysis/Raman effect (Atomic).
23. Design and study of pass filters.
24. Michelson Interferometer.
25. Fabry parot Interferometer.
26. Determination of velocity of Ultrasonic waves.
27. Study of Elliptically polarised light by Babinet Compensator.
28. Verification of Cauchey's Dispersion relation
29. [illegible]

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M. Sc PHYSICS FINAL

Paper-V	:	Advanced Quantum Mechanics and Introductory Quantum Field	Max Marks 100 Time 3 hrs
Paper-VI		Nuclear Physics	Max Marks 100 Time 3 hrs.
Paper-VII	:	Statistical and Solid State Physics	Max Marks 100 Time 3 hrs.
Paper-VIII	:	(A) Microwave Electronics	Max Marks 100 Time 3 hrs.
		OR	
Paper-VIII	:	(B) Plasma Physics	Max Marks 100 Time 3 hrs.

PAPER - V : ADVANCED QUANTUM MECHANICS AND INTRODUCTORY QUANTUM FIELD THEORY

Max. Marks 100 Duration 3 hrs.

Note : In all Ten questions are to be set. Five from each section. Candidates are required to attempt five questions in all, taking at least two questions from each section.

Section A

1. **Scattering (non-relativistic) :** Differential and total scattering cross section, transformation from CM frame to Lab frame, solution of scattering problem by the method of partial wave analysis, expansion of a plane wave into a spherical wave and scattering amplitude, the optical theorem, Applications - scattering from a delta potential, square well potential and the hard sphere scattering of identical particles, energy dependence and resonance scattering. Breit-Wigner formula, quasi stationary states.

The Lippman-Schwinger equation and the Green's function approach for scattering problem, Born approximation and its validity for scattering problem, Coulomb scattering problem under first Born approximation in elastic scattering.

2. **Relativistic Formulation and Dirac Equation : Attempt for relativistic formulation of quantum theory, The Klein-Gordon equation, Probability density and probability current density, solution of free particle K.G. equation in momentum representation, interpretation of negative probability density and negative energy solutions.**

Dirac equation, orthogonality and completeness relations for Dirac spinors, interpretation of negative energy solution and hole theory.

3. **Symmetries of Dirac Equation :** Lorentz covariance of Dirac equation, proof of covariance and derivation of Lorentz boost and rotation matrices for Dirac spinors, Projection operators involving four momentum and spin, Parity (P), charge conjugation (C), time reversal (T) and CPT operators for Dirac spinors, Billinear covariants, and their transformations behaviour under Lorentz transformation, P.C.T. and CPT, expectation values of co-ordinate and velocity involving only positive energy solutions and the associated problems, inclusion of negative energy solution, Zitter bewegung, Klain paradox.

4. **The Quantum Theory of Radiation :** Classical radiation field, transversality condition, Fourier decomposition and radiation oscillators, Quantization of radiation oscillator, creation, annihilation and number operators, photon states, photon as a quantum mechanical excitations of the radiation field. fluctuations and the uncertainty relation, validity of the classical description, matrix element for emission and absorption, spontaneous emission in the dipole approximation, Rayleigh scattering, Thomson scattering and the Raman effect. Radiation damping and Resonance fluorescence.

Section B

5. **Scalar and vector fields :** Classical Lagrangian field theory, Euler-Lagrange's equation, Lagrangian density for electromagnetic field. Occupation number representation for simple harmonic oscillator, linear array of coupled oscillators, second quantization of identical bosons, second quantization of the real Klein Gordan field and complex Klein-Gordan feld, the meson propagator.

6. The occupation number representation for fermions, second quantization of the Dirac filed, the femion propagator, the e.m. interaction and gauge invariance, covariant quantization of the free electromagnetic field, the photon propagator.

7. S-matrix, the S-matrix expansion, Wick's theorem, Diagrammatic representation in configuration space, the momentum representation, Feynman diagrams of basic processes, Feynman rules of QED.

8. **Applications of S-matrix formalism:** the Coulomb scattering, Bhabha scattering, Moller scattering, Compton scattering and pair production.

Reference Books :

1. Ashok Das and A.C. Millissiones : Quantum Mechanics - A Modern Approach (Garden and Breach Science Publishers).
2. E. Merzbaker : Quantum Mechanics, Second Edition (John Wiley and sons)

3. Bjorken and Drell : Relativistic Quantum Mechanics (MGraw Hill)
4. J.J. Sakurai : Advanced Quantum Mechanics (John Wiley)
5. F. Mandal & G. Shaw, Quantum Field Theory (John Wiley)
6. J.M. Ziman, Elements of Advance Quantum Theory, (Cambridge University Press).

PEPER - VI : NUCLEAR PHYSICS

Max. Marks 100 **Duration 3 hrs.**

Note : In all Ten questions are to be set. Five from each section. Candidates are required to attempt five questions in all, taking at least two questions from each section.

Section A

1. **Two Nucleon system and Nuclear Forces :** General nature of the force between nucleons, saturation of nuclear forces, charge independence and spin dependence, General forms of two nucleon interaction, central, noncentral and velocity dependent potentials, Analysis of the ground state ($3S_1$) of deuteron using a square well potential, range-depth relationship, excited states of deuteron, Discussion of the ground state of deutron under noncentral force, calculation of the electric quadrupole and magnetic dipole moments and the D-state admixture.

2. **Nucleon-Nucleon Scattering and Potentials :** Partial wave analysis of the neutron-proton scattering at low energy assuming central potential with square well shape, concept of the scattering length, coherent scattering of neutrons by protons in (ortho and para) hydrogen molecule; conclusions of these analyses regarding scattering lengths, range and depth of the potential; the effective range theory (in neutron-proton scattering) and the shape independence of nuclear potential; A qualitative discussion of proton-proton scattering at low energy; General features of two-body scattering at high energy Effect of exchange forces; Phenomemonological Hamada-Johnston hard core potential and Reid hard core and soft core potentials; Main features of the One boson Exchange Potentials (OBEP) no derivation.

3. **Interaction of radiation and charged particle with matter (No derivation) :** Law of absorption and attenuation coefficient; Photoelectric effect, Compton scattering, pair production; Klein-Nishina cross sections for polarized and unpolarized radiation, angular distribution of scattered photon and electrons, Energy loss of charged particles due to ionization, Bremstrahlung; energy target and projectile dependence of all three processes, Range-energy curves; Straggling.

4. **Experimental Techniques : Gas filled counters; Scintillation**

[illegible] Cerenkov counters; Solid state detectors; Surface barrier detectors; [illegible] circuits used with typical nuclear detectors; Multiwire proportion chambers; Nuclear emulsions, techniques of measurement and analysis of tracks. Proton synchrotron; Linear accelerations, Acceleration of heavy ions.

Section B

5. ***Nuclear shell model*** : Single particle and collective motions in [illegible] Assumptions and justification of the shell model, average shell potential, [illegible] coupling; single particle wave functions and level sequence; magic numbers; shell model predictions for ground state parity; angular momentum, [illegible] and electric-quadrupole moments; and their comparison with [illegible] configuration mixing; single particle transition probability [illegible] the shell model; selection rules; approximate estimates for the [illegible] probability and Weisskopf units; Nuclear isomerism.

6. **Collective nuclear models** : Collective variable to describe the [illegible] modes of nuclear motion; Parametrization of nuclear surface; A brief description of the collective model Hamiltonian (in the quadratic approximation); Vibrational modes of a spherical nucleus, Collective modes [illegible] deformed even-even nucleus and moments of inertia; Collective spectra [illegible] electromagnetic transition in even nuclei and comparison with experimental data. Nilsson model for the single particle states in deformed nuclei.

7. **Nuclear gamma and beta decay** : Electric and magnetic multipole [illegible] gamma decay probabilities in nuclear system (no derivations) [illegible] probability. Selection rules; Internal conversion and zero-[illegible]

[illegible] characteristics of weak interaction, nuclear beta decay and [illegible] energy spectrum and Fermi-Kurie plot; Fermi th[illegible] [illegible] conserved selection rules Fermi and Gammow-Teller) for allowed transitions; ft-values; General interaction Hamiltonian for beta decay with parity conserving and non conserving terms; Forbidden transitions; Experimental verification of parity violation; The V-A interaction and experimental evidence

8. **Nuclear Reactions**: Theories of Nuclear Reactions; Partial wave analysis of reaction Cross section; Compound nucleus formation and breakup; Resonance scattering and reaction- Breit-Wigner dispersion formula for s-waves [illegible] cross section; statistical theory of nuclear reactions. [illegible] probability and cross section for specific reactions; The optical model. [illegible] reactions and their simple theoretical description (Butler [illegible]

Reference Books

1. J.M Blatt and V.E. Weisskipf : Theoretical Nuclear Physics
2. Statistical theory of nuclear reactions, Exaparation probability and cross section for specific reaction.
3. L.R.B Elton : Introductory Nuclear Theory, ELBS Pub. London, 1959
4. B.K. Agrawl : Nuclear Physics, Lokbharti Pub. Allahabad.1989
5. M.K. Pal : Nuclear Structure, Affiliated East-West Press.1982).
6. R.R. Roy and B.P. Nigam, Nuclear Physics, Willey-Easter, 1979
7. M.A. Preston & R.K Bhaduri-Structure of the Nucleus, Addision Wesley, 1975
8. R.M. Singru : Introductory Experimental Nuclear Physics
9. England - Techniques on Nuclear Structure (Vol. I)
10. R.D. Evans - The Atomic Nucleus (McGraw - Hills, 1955)
11. H. Enge - Introduction to Nuclear Physics, Addition-Wesley, 1970
12. W.E. Burcham - Elements of Nuclear Physics, ELBS, Longman, 1988
13. B.L. Cohen - Concpt of Nuclear Physics Tata Mc-Graw Hills, 1988
14. E. Segre - Nuclei, Particles Benjamin, 1977
15. I. Kaplan - Nuclear Physics, Addison Wesley, 1963
16. D. Hallidy - Introductory Nuclear Physics, Wiley, 1955.
17. Harvey - Introduction of Nuclear Physics and Chemistry

PEPER-VII : STATISTICAL AND SOLID STATE PHYSICS

Max. Marks 100 Duration 3 hrs.

Note : In all Ten questions are to be set. Five from each section. Candidates are required to attempt five questions in all, taking at least two questions from each section.

Section A

1. **Basic Principles, Canonical and Grand Canonical ensembles:** Concept of statistical distribution, phase space, density of states, Liouville's theorem, systems and ensemble, entropy in statistical mechanics Connection between thermodyanic and statistical quantities micro canonical ensemble, equation of state, specific heat and entropy of a perfect gas, using micro canonical ensemble.

Canonical ensemble, thermodynamic functions for the canonical ensemble, calculation of mean values, energy fluctuation in a gas, grand canonical ensemble, thermodynamic functions for the grand canonical ensemble, density fluctuation[illegible] of translational, rotational and vibrational contributions to the partition function of an ideal diatomic gas. Specific heat of a diatomic gas, ortho and para hydrogen.

Identical particles and symmetry requirement. difficulties with Maxwell-Boltzmann statistics, quantum distribution functions. Bose-Einstein and Fermi-Dirac statistics, Boson statistics and Planck's formula, Bose Einstein condensation, liquid He^4 as a Boson system, quantization of harmonic oscillator and creation and annihilation of Phonon operators, quantization of fermion operators

3. **Theory of Metals :** Fermi-Dirac distribution function, density of states, temperature dependence of Fermi energy, specific heat, use of Fermi-Dirac statistics in the calculation of thermal conductivity and electrical conductivity. Widemann - Franz ratio, susceptibility, width of conduction band, Drude theory of light absorption in metals.

4. **Band Theory :** Block theorem, Kronig Penny model, effective mass of electrons, Wigner-Seitz approximation. NFE model, tight binding method and calculation of density for a band in simple cubic lattice, pseudo-potential method.

Section B

5. **Lattice Vibratuibs and Thermal Properties :** Interrelations between elastic constants C_{11}, C_{12} and C_{44} wave propagation and exparimental determination of elastic constant of cubic crystal, vibrations of linearmono and diatomic lattices. Determination of phonon dispersion by inelastic scattering of neutrons.

6. **Semiconductors :** law of mass action, calculation of impurity conductivity, ellipsoidal energy surfaces in Si and Ge, Hall effect, recombination mechanism, optical transitions and Schockely-Read theory excitons, photoconductivity, photo-Luminescence.

Points line, planar and bulk defects, colour centres, F-centre and aggregate centres in alkali halides.

7. **Magnetism :** Larmor diamagnetism. Paramagnetism, Curie Langevin and Quantum theories. Susceptibility of rare earth and transition metals. Ferromagnetism: Domain theory. Veiss molecular field and exchange. spin waves: dispersion relation and its experimental determination by inelastic neutrons scattering, heat capacity. Nuclear Magnetic resonance: Conditions of resonance. Black equations. NMR-experiment and characteristics of an absorption line.

Giver and AC and DC, Josephson tunnelings.

(b) Cooper pairs and derivation of BCS Hamiltonian, results of BCS theory (no derivation).

Reference Books :

1. Huag : Statistical Mechanics
2. Reif : Fundamentals of Statistical and Thermodynamical Physics
3. Rice : Statistical mechanics and Thermal Physics
4. Kittle : Elementary statistical Mechanics
5. Kittle : Introduction to Solid State Physics
6. Palierson : Solid State Physics
7. Levy : Solid State Physics
8. Mckelvy : Solid State and Semi-conductor Physics.

PEPER - VIII : (A) MICROWAVE ELECTRONICS

Max. Marks 100 — Duration 3 hrs

Note : In all Ten questions are to be set. Five from each section. Candidates are required to attempt five questions in all, taking at least two questions from each section.

Section A

1. Introduction to microwaves and its frequency spectrum. Application of microwaves.

Wave guides : (a) Rectangular wave guides: Wave Equation & its solutions, TE&TM modes. Dominant mode and choice of wave guide Dimensions Methods of excitation of wave guide.

(b) Circular wave guide-wave equation & its solutions TE, TM & TEM modes.

(c) Attenuation - Cause of attenuation in wave guides, wall current & derivation of attenuation constant, Q of the wave guide.

2. (a) **Resonators :** Resonant Modes of rectangular and cylindrical cavity resonators, Q of the cavity resonators, Excitation techniques, Introduction to Microstrip and Dielectric resonators, Frequency meter.

(b) Ferrites : Microwave propagation in ferrites, Faraday rotation. Devices employing Faraday rotation (isolator, Gyrator Circulator). Introduction to single crystal ferromagnetic resonators, YIG tuned solid state resonators.

3. **Microwave tubes: Space charge ...**

Electric & Magnetic field of oscillations. Modes of oscillation & operating characteristics.

Traveling wave tubes : O & M type travelling wave tubes.

Gyrotrons: Constructions of different Gyrotrons, Field - Particle interaction in Gyrotron.

4. **Microwave Measurement :**
   a. Microwave Detectors: Power, Frequency, Attenuation, Impedance using smith chart, VSWR, Reflectometer, Directivity, coupling using direction coupler.
   b. Complex permittivity of material & its measurement: definition of complex of Solids, liquids and powders using shift of minima method.

Section B

1. (a) Avalanche Transit Time Device: Read Diode, Negative resistance of an avalanching p-n Junction diode IMPATT and TRAPATT Oscillator.
   (b) Transferred Electron Device: Gunn effect, two velley model, High field Domains, Different Modes for Microwave generation.
   (c) Passive Devices: Termination (Short circuit and matched terminations) Attenuator, phase changers, E&H plane Tees, Hybrid Junctions. Directional coupler.
2. Parametric Amplifier: Varactor, Equation of Capacitance in Linearly graded & abrupt p-n junction, Manely Rowe relations, parametric upconvertor and Negative resistance parametric amplifier, use of circulator, Noise in parametric amplifiers.
3. Microwave Antennas: Introduction to antenna parameters, Magnetic Currents, Electric and magnetic current sheet, Field of Huygen's source, Radiation from a slot antenna, open end of a wave guide and Electromagnetic Horns. Prabolic reflectors, Lens antennas.
   Radiation fields of Microstrip wave guide, Microstrip wave guide, Microstrip antenna calculations, Microstrip design formulas.
4. Microwave Communication: (a) LOS microwave systems, Derivation of LOS communication range, OTH microwave systems. Derivation of field strength of tropospheric waves. Transmission interference and signal damping. Duct propagation.
5. Satellite Communication : Satellite frequencies allocation, Synchronous satellites, Satellite orbits, Satellite location with

Reference Books:

1. Electromagnetic waves & Radiating Systems : Jorden & Balmain.
2. Theory and application of microwaves by A.B. Brownwell & R.E. Beam (McGraw Hill)
3. Introduction to microwave theory by Atwater (McGraw Hill).
4. Principles of microwave circuit by G.C. Montgomery (Mc Graw Hill)
5. Microwave Circuits & Passive Devices by M.L. Sisodia and G.S. Raghuvanshi (New Age International, New Delhi)
6. Foundations of microwave engineering by R.E. Collin. (McGraw Hill).
7. Microwave Semiconductor Devices and their Circuit applications by H.A. Watson
8. Microwave by M.L. Sisodia and Vijay Laxmi Gupta. New Age, New Delhi.
9. Antenna Theory, Part-I by R.E. Collin & F.J. Zucker (McGraw Hill, New York)
10. Microstrip Antennas by Bahl & Bhartiya (Artech House, Messachausetts)
11. Antenna Theory Analysis by C.A. Balanis Harper & Row, Pub. & Inc. New York.
12. Antenna Theory Analysis by E.A. Wolf (J. Willey & Sons)
13. Antenna Theory & Design by RS Elliott (LPHI Ltd. New Delhi)
14. Microwave electronics by R.F. Sooboo (Addisen Westey pubblic company.).
15. Microwave Active Devices, Vacuoums by M.L. Sisodia new Age International New Delhi.
16. Semiconductors & Electronics device by A. Barle vs (PHI, India).
17. Solid State physical electronics by A.Vanderziel, (PHI, India).
18. Hand book of microwave measurement Vol-II by M. Sucher & J. Fox (Polytechnic Press, New York).
19. Microwave devices & circuits by S.Y.Liao(PHI, India).
20. Microwave Principles by H.J. Reich (CBS).
21. Simple microwave technique for measuring the dielectric parameters of solids & their powder by J.M. Gandhi, I.S. Yadav, J. of pure & applied physics Vol. 30, pp-427-431, 1992.

PEPER - VIII (B) : PLASMA PHYSICS

Max. Marks 100

Section A

1. **Basic properties and occurence.** Definition of plasma. Criteria [illegible] plasma behaviour. Plasma oscillation. Quasineutrality and Debye shielding. The plasma parameter. natural occurence of plasmas. Astrophysical plasmas. Plasma in Magnetosphere and ionosphere. introduction to various theoretical approaches : Kinetic, Multi-Fluid and single fluid.

2. **Charged particle motion and drifts :** Guiding centre motion of a charges particle. Motion in (i) uniform electric and magnetic fields (i) gravitational and magnetic fields. Motion in non-uniform magnetic field (i) Grad B perpendicular to B, Grad B drift and curvature drift (ii) Grad B parallel to B and principle of magnetic mirror. Motion in non-uniform electric field for small larmour radius. Time varying electic field and polarization drift. Time varying magnetic field adiabatic invariance of magentic moment.

3. **Diffiusion and resistivity:** Collision and diffusion parameters. [illegible] of a plasma by diffusion. ambipolar diffusion. Diffusion across a [illegible] field. Collision in fully ionized plasma,. Plasma resistivity. Diffusion [illegible] plasmas. Solution of Diffusion equation. plasma production [illegible]. Thermal ionization. saha equation. Brief discussion of methods [illegible] plasma production . Steady state glow discharge. microwave [illegible] and induction discharge. Double plasma machine. elementary [illegible] plasma diagnostics. electrostatic and magnetic probes.

4. **MHD power generation.** basic principle and working of MHD [illegible] generator. Conductivity of gaseous working fluid. Basic fluid equations. [illegible] Ohm's law. Faraday and Hall generators. performance [illegible] and electrical efficiency of Faraday and Hall Generators.

Section B

1. **Waves in plasma:** electron plasma waves. Ion Waves. [illegible] electron oscillations perpendicular to B, upper hybrid oscillations. [illegible] waves perpendicular to B. ion cyclotron waves, Lower hybrid [illegible]. Electromagnetic waves in field free plasma. Electromagnetic waves [illegible] B. Cut offs and resonances. Electromagnetic waves parallel [illegible] field. Hydromagnetic waves. Magnetosonic waves.

2. **Equilibrium and Stability :** Hydromagnetic equilibrium. [illegible] of magnetic field into a plasma. Classification of instabilities. The [illegible] instability. Kinetic treatment of plasma oscillations and landau [illegible] physical explanation.

3. Non-linear effects : The Sagdeev potential. Derivation of KdV [illegible] acoustic waves. Soliton solution in one dimension. Elementary [illegible]

4. **Controlled thermonuclear fusion :** Potentials and problems of controlled thermonuclear fusion. Ignition temperature and Lawson criteria Magnetic confinement. Simple discussion of Tokrmak, stellarators, multipoles and Z-pinch. Idea about intertial confinement and laser fusion. Methods of plasma heating and problems of fusion.

References :

1. F.F. Chen: An Introduction to Plasma Physics (Plenum Press) 1974.
2. Boley : Plasmas : Laboratory and Cosmic.
3. W.B. Kunkel : Plasma Physics in theory and Application.
3. J.A. Bittencomt Fundamentals of Plasma Physics (Pergamon Press) 1986
4. Huddlestone & Leonord : Plasma Diagnostic Techniques.
5. R.C. Davidson : Methods in Non-linear Plasma theory. 1972.
6. Holt and Haskel : Foundations of Plasma.

LIST OF EXPERIMENTS FOR M.Sc FINAL

Scheme :

The examination will be conducted for two days. 6 hrs. each day. The distribution of the marks will be as Follows :

Two experiments	Marks
Viva	120
Record	40
	40
Total	200
Minimum Pass Marks	72

LIST OF EXPERIMENTS (any eighteen)

1. To determine half-life of a radio isotope using GM counter
2. To study absorption of particles and determine range using at least two sources.
3. To study characteristics of a GM counter and to study statistical nature of radioactive decay.
4. To study spectrum of -β particles using Gamma ray spectrometer
5. To calibrate a scintillation spectrometer and determine energy of γ rays from an unknown source

formula.

8. To study temperature variation of resistivity for a semi-conductor and to obtain band gap using four probe method.
9. To study hall effect and to determine hall coefficient.
10. To study the variation of rigidity of a given specimen as a function of the temperature.
11. To study the dynamics of a lattice using electrical analog.
12. To study ESR and determine g-factor for a given spectrum.
13. To determine ultrasonic velocity and to obtain compressibility for a given liquid.
14. Study the characteristics of a given Klystron and calculate the mode number, E.T.S. and transit time.
15. Study the simulated L.C.R. transmission line (audio frequency) and to find out the value for and Zo experimentally from the graph.
16. Study the radiation pattern of a given Pyramidal horn by plotting it on a Polar graph paper. Find the half power beamwidth and calculate its gain.
17. Find the dielectric constant of a given solid (Teflon) for three different lengths by using slotted section.
18. Find the dielectric constant of a given liquid (organic) using slotted section of K-band.
19. Verification of Bragg's law using microwaves..
20. Determination of Dielectric Constant of a liquid by lecher wire.
21. Study of a Heat Capacity of Solids.
22. Study of lattice dispersion.

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