M.Phil. Physics Examination 2007

Paper –I: Advance Quantum Mechanics

Unit -I

1. Necessity of field theory; Classical Lagrangian field theory, Variational Principle and Euler Lagrange's equation, Lagrangian density, second quantization of the real Klein-Gordon Field and Complex Klein-Gordan field, Dirac Field. Covariant quantization of electromagnetic field.

Unit -II

2. Meson, Fermion and Photon propagator, 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.

Unit -III

3. Applications of S-matrix formalism : Lepton pair production in electron-positron collisions, Coulomb scattering, Bhabha scattering, Moller scattering, Compton scattering and Pair production.

Unit -IV

4. The Second Order Radiative corrections of QED, the photon self energy, the electron self energy, the external line renormalization, the vertex modification. Applications – the anomalous magnetic moments, the lamb shift.

Reference Books :

1. Quantum Field Theory by F. Mandl & G. Shaw (John-Wiley & Sons).
2. Relativistic Quantum Mechanics by J.D. Bjorken & S. Drell (McGraw Hill Book Co.).
3. Advanced Quantum Mechanics by J.J. Sakaurai.
4. Elements of Advanced Quantum Theory by J.M. Ziman. (Cambridge University Press).

Syllabus

Advanced Nuclear Physics

on Annihilation Spectroscopy: Positron Sources, interaction of positron with nnihilation process, 1-2-3 gamma, free annihilation, quenching of positronium, of positrons in solids, 2D-Angular correlation of annihilation radiation, Basic of Positron life time measurement, Doppler broadening, Two gamma, three nnihilation probability ratio. Positron moderation through matter. Variable sitron beams and their applications. Positron Annihilation Tomography (PAT). nomentum density and Fermi surface studies.

on Scattering :Interaction of gamma ray with matter, photoelectric effect, pair n and Compton scattering and their dependence on various physical parameters, shift at 160°-180°. Beam profile, Back scattering geometry and Compton eter, HP Ge detector, Energy and momentum Spectrum of electrons, Magnetic gy , Magnetic Compton scattering, Experiments with Synchrotron Radiation th illustration of scattering of polarized and unpolarized beam, Determination of entum density distribution.

n diffraction (ND): Source of neutrons, Interaction of neutrons with matter, length, structure factor, magnetic form factor, Diffractometer, Need for high lux for recording a powder diffraction pattern, characterization of magnetic Ferro and anti-ferromagnetic in particular, Magnetic structure determination of erials-Rietveld method for fitting ND pattern of an unknown magnetic material

ar γ-ray resonance Fluorescence (NGR): Mossbauer's discovery- ^{191}Ir it, basic principles of Mossbauer effect, resonance cross section, Recoil-f- lependence of f-fraction on various parameters- Einstein Model, Natural line width, Isomer shift, Electric quadrupole interaction, Nuclear Zeeman splitting as ^{57}Fe Mossbauer spectroscopic parameters. Mossbauer spectrometer, Application of Mossbauer spectroscopy in Solid State and Nuclear Physis – with illustrations and results, Recent experiments at Mars – (MIMOS), Lattice dynamical application of Mossbauer spectroscopy using Synchrotron radiation source.

Reference Books:

1. Positron Annihilation by A. Hotozarvi Kolk (Springer Verlag)
2. Compton scattering :B.William.
3. Magnetic Compton Scattering: Ed. M.Cooper
4. Neutron diffraction : G.E. Bacon
5. The Rietveld Method: R.A. Young, International Union of Crystallography, Oxford Science publications 2002
6. Mossbauer Effect and its publications : V.G.Bhide Tata McGraw Hill Pub. Co. Ltd., New Delhi 1973
7. WWW. Mossbauer Org. and other related websites (e.g. Phys. Rev. Focus of American physical society)

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Paper III(c) - Plasma Physics

Note - Four questions taking one questions from every part with 100 per cent internal choice are to be set in the question paper. Candidates will be required to answer all the four questions.

1. Maxwell's equations. Derivation and interpretation of Maxwell's equations with time varying fields. Vector and scalar potentials and gauge transformations. Green Function for the wave equation. Derivation of equations of macroscopic electromagnetism. Conservation of energy, momentum and angular momentum for a system of charged particles and electromagnetic fields. Poynting theorem for harmonic fields.

2. <u>Nonlinear equations and singular perturbation methods</u>

Free oscillations of a pendulum. Operational analysis of nonlinear dynamical systems. Kryloff and Bogoliuboff method. Topological methods. Nonlinear conservative systems. Phase trajectories of the van der Pol equation. Singular perturbation methods. Asymptotic series and perturbations. Secular perturbation. Poincare's method, method of strained coordinates, variational method.

Fundamental concepts in wave problems. The formal derivation of asymptotic equations. Reductive perturbation method. KBM method. The method of multiple scales.

3. <u>The Vlasov theory of Plasma Waves and instability</u>

Solution of linearized Vlasov equation for electrostatic perturbations. Langmuir, ion-sound waves, Landau damping. Electromagnetic waves. The Vlasov theory of small amplitude waves in a uniformly magnetized plasma. Waves along and perpendicular to uniform magnetic field. Waves in an inhomogeneous magnetized hot plasma. Nonlinear electrostatic BGK waves. The two stream instability. The Nyquist method and Penrose criterion for stability. Ion-acoustic instability. Instabilities in anisotropic plasmas.

4. Detailed study of any <u>ONE</u> of the following topics or any other topic of active research area:

i) Nonlinear Vlasov theory of Plasma waves and instabilities.
ii) Strong wave Particle interactions.
iii) Solitons in Plasmas.
iv) Electrostatic double layers
v) Neoclassical transport theory
vi) Z-pinch, Toroidal equilibria and Extrap.

Note – The topic under unit 4 will be decided by the teacher concerned every year.

<u>References</u>

For Unit 1: J.D. Jackson, Classical Electrodynamics Chapter 6.

For Unit 2: Pipes and Harvill, Applied Mathematics for Engineers and Physicists, III edition, Chapter 15.
A. Jeffrey and T. Kawahara, Asymptotic methods in non linear wave theory, Chapters 2 and 3.

For Unit 3 and 4: N.A. Krall and A.W. Trivelpiece, Principles of Plasma Physics, Mc-Graw Hill, Chapter 8.

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Paper III (b) High Energy Physics

Note – Four questions taking one question from every part with 100 per cent internal choice are to be set in the question paper. Candidates will be required to answer all the four questions.

1.(a) Qualitative Introduction

Particles, resonances, classification into Baryons, mesons, leptons and gauge bosons. Quark flavours strangeness, charm, bottom and top. Additive conservation laws, charge, Baryon number, lepton number strangeness and charm numbers, particle decays, Quark structure of hadrons.

(b) Experimental study of High Energy nucleus-nucleus interaction

Experimental parameters : Cross section, Multiplicity distributions, angular and rapidity distributions. Two particle and many particle correlations, comparison of hadron-hadron, Hadron-nucleus and nucleus-nucleus collisions.

Models: Fire Ball model, Additive quark model, Lund model, brief description of these models for nucleus-nucleus interactions.

Review of important results in High Energy Heavy Ion Interactions about Projectile, Target fragmentation and multiparticle production, Observation of neutron rich isotopes, Anomalon effect, rch for collective phenomena in the emission of relativistic α particles, Analysis of multiplicity distributions in terms of negative Boltzman Distributions. Analysis of rapidity distributions, signal for quark gluon plasma in ultrarelativistic High Energy Heavy Ion Interactions.

2.(a) Modern detectors

Position detectors: Multiwire proportional chamber, drift chamber, Time projection chamber, silicon strip detectors.

Particle identification – Chernkov detectors, Transition radiation detectors, Multiple ionisation measurement.

Energy measurement – Electron photon shower counters, hadron calorimeters, calibration and monitoring of calorimeters.

Nuclear emulsions — measurements of position, momentum energy, charge etc, Qualitative description of NA38 (detector assembly used for H.E. heavy Ion interactions).

(b) Relativistic kinematics

Lorentz transformation and four vectors, Lorentz invariants, Mandelstern variables, available energy in lab and CM frames, advantage of intersecting storage rings, principle of stochastic cooling.

3. LAGRANGIAN FORMULATION, SYMMETRIES AND GAUGE FIELDS

Lagrangian formulation of particle mechanics, the real scalar field, variational principle and Noether's theorem, conservation of energy, momentum and angular momentum, complex scalar fields, U(1) gauge transformation, U(1) local gauge transformation, interaction with electromagnetic field, covariant derivative, Dirac fields and local and global U(1) gauge transformations.

4. ELECTROWEAK INTERACTIONS

Early history of weak interactions – Fermi ere, Parity nonconservation, the V–A law, difficulties of Fermitype theories, the naive intermediate boson hypothesis. Yang Mill field and SU(2) gauge invariance, $SU(2)_L XU(1)$ model. Spontaneous symmetry breaking, couplings of leptons and quarks to gauge fields, Leptons and quarks couplings to the scalar field, Feynman rules for the electroweak $[SU(2)_L XU(1)]$ model (no derivation), muon decay and the V–A law, general muon-decay amplitude, Michel parameters, connection to experimental facts. the process $e^+e^- \rightarrow \mu^+\mu^-$ single photon exchange contribution, weak electromagnetic interference effects in $e^+e^- \rightarrow \mu^+\mu^-$. The decays and widths of $Z^0 \rightarrow e^+e^-$, $\mu^+\mu^-$, and $W^\pm \rightarrow e^\pm \nu$, $\mu^\pm \nu$.

The scope of the syllabus is defined by the following:

Part

1(a) Cheng and O'Neil, Elementary Particle Physics, Chapter 1.

1(b) Review articles and research papers

2(a) Konrad Kleinknecht, Detectors For Particle Radiation Chapters 3,5,6.

2(b) D. Griffiths, Introduction to Elementary Particles, Chapter 3, and also Cheng and O'Neil.

3. L.H. Ryder, Quantum Field Theory, Chapter 3 (Cambridge University Press 1985).

4. E.D. Commins and P.H. Bucksbaum, Weak Interactions of Leptons and Quarks, Cambridge University Press (1983).

Additional References

1. C. Itzykson and J.B. Zuber, Quantum Field Theory Mc. Graw Hill Book Co.

2. G. Kane, Modern Elementary Particle Physics (Addison -Wesley Publishing Co. (1987).

3. C. Quigg, Gauge Theories of the strong, Weak and Electromagnetic interactions, (The Benjamin Publishing Co. 1983).

4. P.H. Frampton, Gauge Field Theories, the Benjamin Cummings Pub. Co. 1987).

5. T.D. Lee, Particle Physics and introduction to field theory, (Harwood, Newyork, 1981).

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Paper III (a) - Condensed Matter Physics

Note - Four questions, taking one question from every part with 100 per cent internal choice are to be set in the question paper. Candidates will be required to answer all the four questions.

Part 1 : Electronic structure (Theoretical)

Introduction: One-electron approximation, Energy-band problem, Energy-band methods, Brief history of Linear methods.

Canonical band theory: Muffin-Tin orbitals and tail cancellation, structure constants and canonical bands, potential functions and Wigner-Seitz rule. Potential parameters, Unhybridised and Hybridised bands, State densities and energy scaling.

One-electron states in a Single sphere: Radial basis functions, partial waves and their energy derivatives, logarithmic derivatives and Laurent expansion, Potential function and band-width, Matrix elements and variational estimate of energies.

The Linear method: Partial waves for a single Muffin-Tin, MT Orbitals, expansion theorem for MTO tails, Energy-independent MTO, The LCMTO Secular matrix, LMTO method.

Atomic-Sphere Approximation (ASA): The kinetic energy, Atomic sphere and the ASA, Muffin-Tin orbitals in the ASA, wave functions and L character, Projected state density and density of electrons. (Qualitative discussion only).

Part 2: Electronic Structure (experimental determination)

(Basic principles, experimental technique and results are to be discussed).

Momentum density and Fermi surface: de Haas-van Alphen effect, positron Annihilation spectroscopy and Compton scattering.

Band structure and Density of states: Photoemission from solids (integral and angle resolved methods), Band spectroscopy, inverse photoemission.

Application of Synchrotron Radiation: Salient features, flux and spectral distribution, Discussion of various components of a synchrotron Radiation facility for condensed matter research.

Part 3 : Magnetism

Introduction: Survey of magnetic properties of rare-earth salts and metals, transition metals and their alloys.

Localised Electron Magnetism: Weiss molecular field, Brilluoin function for paramagnets, extension to ferromagnetic ordering, departure from Weiss theory. Antiferromagnetism and ferrimagnetism (qualitative discussion in two-sub lattice model). Ferrites (only results).

Itinerant Electron Magnetism: Paramagnetism of free electrons, Ferromagnetism of band electrons, collective electron model due to Stoner, Rigid band model (qualitative discussion only). Slater-Pauling curve.

Magnetism in high temperature: Application of Landau's region (close to transition point), theory of second order phase transition, Bethe-Peierls-Weiss (BPW) approximation.

Domain Magnetism: Basic principles (magnetocrystalline anisotropy, magnetostatic energy, domain walls, magnetostriction, magnetization curve and domain wall equilibrium, single domain particles), soft and hard magnetic materials, Thin magnetic films and bubble domains.

Experimental techniques: (Basic principles, experimental technique and typical results are to be discussed for the following techniques).

Mossbauer Spectroscopy, Neutron diffraction, Vibrating sample magnetometer.

Part 4: Disordered Materials and Glasses

Disordered Materials: Distinction between crystalline and disordered materials, Static and dynamic structure factors for liquid metals, Pair-correlation function, and their relationship with elastic and inelastic X-ray scattering from liquids (only discussion of results). Single particle and collective modes, Phonon dispersion. Extension to liquid alloys. Concentration

<u>Glasses</u>: Glass transition, structural models, Thermodynamics of Glass transition, Dynamic theory of glass transition, Optical, thermal, mechanical, electrical and magnetic properties of glasses (simple examples) and their interpretation. Phonon dispersion in two-component metallic glasses using atomic theories and psuedopotential approach.

References

Part 1

1. It is based on Chapters 1 to 7 from the LMTO Method by H.L. Skriver, Springer-Verlag, Solid-State Sciences 41.
2. Electronic band structure and its applications (Ed) M. Yussouff. Lecture notes in Physics Vol. 283, (Springer-Verlag).

Part 2

3. Compton Scattering (Ed). B. Williams, McGraw Hill Co. (1977).
4. Photoemission in Solids (Springer-verlag) by Ley and Cardons.
5. Sychrotron Radiation Research (Ed). H. Winick and S. Doniach (Plenum, New York 1980).
6. Inverse Photoemission by N.V. Smith (1988).

Part 3

7. The structures and Properties of Solids 6 (The Magnetic Properties of Solids) by J. Crangle, Edward Arnold (Publishers) Ltd, London (1977),
8. Physics of Magnetism, by Soshin Chikazumi, Robert E. Kreiger Publishing Co., Florida (John Wiley and Sons, Inc) (Reprint 1978).

9. Introduction to the theory of Magnetism, by D. Wagner, Pergamon Press, Oxford (1972).
10. Mossbauer effect and its applications, by V.G. Bhide, Tata McGraw Hill Publishing Co. Ltd, New Delhi (1975).

Part 4

11. Physics and Chemistry of liquids, by Beer, Noncel Dekkev. 1972.
12. Introduction to liquid state Physics, by P.A. Egelslaff, Academic Press, 1967.
13. An introduction to the theory of liquid metals, by T.E. Faber, Cambridge Press.
14. Metallic Glasses, Contemporary Physics, Vol. 21, No. 1 43-75 (1980).
15. A unified theory of melting, crystallization and Glass formation, Coll. C2, No.4, Vol. 36 (1975) 235, by Cotterill and Jensen.
16. Liquid Metals, by N.H. March
17. Glassy Metals I, by H. Beck and H.J. Guntherodt, Springer-verlag NY).