Himachal Pradesh University
Department of Physics
(NAAC Accredited ‘A’ Grade University)

Proposed Course of Study and Syllabi
Ph.D Course work (Physics)
(Effective from Academic Session November 2024 onwards)

Ph.D Course work (Physics)

S. No.	Course code	Course	Credit
1.	RPE-PhD	Research and Publication Ethics	2
2.	CWDPHY-101	Research Methodology	5
3.	CWDPHY-102	Elective Course	5

Scientific article writing skill:

Student has to review Ph.D thesis/research articles (concerned specialization) in consultation with mentor. He/she has to write a report (in research article form) and give presentation in front of Departmental Council after completion of Ph. D course work within three months.

COURSE CODE: CWDPHY- 101

Name of the Course: Research Methodology

(Credit Weightage - 5)

Max Marks: 100 **Time: 3 hrs.**

Instructions for paper setters and candidates: *Eleven questions will be set in all. Question No. 1 section A, is compulsory covering whole syllabus of the course and consist of 10 part of short answer type question and the candidate has to attempt any 8 (eight). Question No. 2 to 10, section B, shall be set from unit 1-5. Examiner has to set 02 (two) questions from each unit, i.e., from unit-I, unit-II, unit-II, unit-IV and unit-V, respectively. Candidate has to attempt one question from each unit, i.e., total 5 (five) question from section B. Question No.1 section A will be of 40 (forty) marks and section B will be of 60 marks, each question will be of 12 (twelve) marks.*

Objectives:

- To enable the Ph.D. scholars to learn the philosophy of research, ethics and standard procedures of publications.
- To enable Ph.D. scholars to learn the importance and use of error analysis, numerical methods and some basic experimental techniques used in research.
- To enable students to learn the basics of quantum mechanics and Green's formalism for application in research.

Course Outcomes:

- After completion of the course the students will learn their moral responsibility as a researcher and to become proficient independent researcher.
- After the completion of the course the students will be able to apply the second quantization and Green's function approach to solve research problems independently.

Unit-I

Data Collection and Error Propagation: Primary and secondary data, Methods of collecting primary data, Sources of secondary data, Processing and analysis of data. Errors as uncertainties, inevitability of uncertainties, importance of knowing the uncertainties and examples, estimating uncertainties in reading scales and in repeatable measurements.
Best estimate, significant figures and discrepancies, comparison and measured and accepted values, fractional uncertainties, multiplying two measured numbers with examples, uncertainties in direct measurements, square-root rule for counting experiments, sums and differences, products and quotients, independent uncertainties in a sum, propagation of uncertainties step-by-steps with examples.

Unit-II

Statistical Methods and Error Analysis: Random and Systematic Errors, The Mean and Standard Deviation, The standard deviation as uncertainty in a single measurement, the standard deviation of the mean with examples, Histograms and Distributions, Limiting Distributions, the Normal Distribution, Justification of the Mean as the Best Estimate, the problem of rejecting data and Chauvenet's criterion,

Least-Square fitting, Covariance and Correlations, The Binomial Distributions: Definition and Properties, The Gauss Distribution for Random Errors, Applications: testing of hypothesis, the Poisson Distributions: Definition and Properties, subtracting a background. The Chi-square test for a distribution: general definition of chi-square, degrees of freedom and reduced chi-square.

Unit-III

Methods of crystal growth: Solution methods, Melt methods, Homogeneous nucleation and heterogeneous nucleation, Energy of formation of a nucleus

Preparation of Amorphous Materials: Introduction to amorphous materials & conducting mechanism, Melt Quenching technique, Thermal Evaporation method, Ball milling

Ceramic material preparation: Introduction to ceramic materials, properties, preparation; Recrystalization and Grain Growth, solid state sintering, sintering with reactive liquid, pressure sintering. Synthesis of Nano-Scale, ceramics powder.

Unit-IV

Quantum Techniques; Time Evolution and the Schrödinger Equation; Time Evolution Operator, The Schrodinger Equation, Energy Eigen Kets, Time Dependence of Expectation value, Spin Precession, Correlation Amplitude and the Energy-Time Uncertainty Relation. **The Schrodinger Versus the Heisenberg Picture;** Unitary Operators, State Kets and Observables in the Schrodinger and the ¨ Heisenberg Pictures, The Heisenberg Equation of Motion, Free Particles: Ehrenfest's Theorem, Base Kets and Transition Amplitudes. **Schrodinger's Wave Equation;** Time-Dependent Wave Equation, The Time-Independent Wave Equation, Interpretations of the Wave Function, The Classical Limit.

Systems and Finite Rotations; Rotation Operator for Spin, Spin Precession Revisited, Neutron Interferometry Experiment to Study 2π Rotations, Pauli Two-Component Formalism, Rotations in the Two-Component Formalism. **SO(3), SU(2), and Euler Rotations;** Orthogonal Group, Unitary Unimodular Group, Euler Rotations.

Density Operators and Pure Versus Mixed Ensembles; Polarized Versus Unpolarized Beams, Ensemble Averages and Density Operator, Time Evolution of Ensembles, Continuum Generalizations, Quantum Statistical Mechanics. **Schwinger's Oscillator Model of Angular Momentum**; Angular Momentum and Uncoupled Oscillators, Explicit Formula for Rotation Matrices.

Unit- V

Green's Function Approach; Green's Functions; Classical Green's function, Linear response of quantum systems, The simple harmonic oscillator, Single-particle Green's functions , Correlation functions, Semi quantitative considerations.

Formal Matters; Double-time Green's functions, Formal properties, Single-particle Green's functions, Higher-order Green's functions, Kramers-Krönig relations, Fluctuation-dissipation theorem, Equations of motion for Green's functions, The thermodynamic potential, An equation for a single-particle Green's function in an external field.

Reference Books:

1. ResearchMethodology:Methods&TechniquesbyC.R.Kothari,3rd Ed.NewAgeInt. Pvt.Ltd.
2. ResearchMethodology-AstepbystepGuideforBeginners-RanjitKumar,PearsonEducation,Singapore
3. Practical Research: Planning Design, by Paul D.Leedy, Prentice Hall
4. An Introduction to Error Analysis, The study of uncertainties in physical measurements by John R. Taylor, Second Edition, University Science Books, California
5. Numerical Methods for Physics by Alejandro L. Gracia, second Edition, Prentice Hall, New Jersey
6. AStudent'sGuidetothestudy,PracticeandToolsofModernMathematics–D.BindnerandM.Erickson(2011)
7. Numerical Methods in engineering &Science–B.S.Grewal(2009)
8. Modern Quantum Mechanics, J.J. Sakurai Publisher Addition Wesley, 1999.
9. G. Rickayzen, Green's functions and condensed matter, Academic press Inc. (London) LTD 1980.
10. An introduction to Nanomaterials and Nanoscience by Asim K Das and Mahua Das, CBS publishers 2020, Dariyaganj, New Delhi
11. Elements of Modern X-ray Physics by Jens Als-Nielsen and Des McMorrow, John Wiley and Sons West Sussex, England 2001

COURSE CODE: CWDPHY- 102(a)

Name of the Course: Advanced Condensed Matter Physics

(Credit weightage - 5)

Max Marks: 100 **Time: 3 hrs.**

Instructions for paper setters and candidates: *Eleven questions will be set in all. Question No. 1 section A, is compulsory covering whole syllabus of the course and consist of 10 part of short answer type question and the candidate has to attempt any 8 (eight). Question No. 2 to 10, section B, shall be set from unit 1-5. Examiner has to set 02 (two) questions from each unit, i.e., from unit-I, unit-II, unit-II, unit-IV and unit-V, respectively. Candidate has to attempt one question from each unit, i.e., total 5 (five) question from section B. Question No.1 section A will be of 40 (forty) marks and section B will be of 60 marks, each question will be of 12 (twelve) marks.*

Objectives

- To make Ph.D. scholars to learn basics concepts of second quantization.
- To train students to use this technique in different formalisms, like electron gas, perturbation theory, random phase approximation, Hatree-Fock approximation, etc., in condensed matter physics.
- To train students to understand electron-phonon interaction and different physical quantities related to superconducting state using second quantization.
- To make students enable to apply Green's function approach in solve condensed mater physics at zero temperature and finite temperature.

Course Outcomes:

- On the completion of the course students will become familiar with second quantization approach used in condensed matter physics.
- After the completion of the course the students will be able to apply above technique to solve condensed matter problems independently.
- On the completion of the course on Green's functions approach in condensed matter physics, students will become more versatile to solve research problems as an independent researcher.

Note: *Problem solving based questions from the topics covered in the curriculum.*

Unit-I

Second quantization: A single electron, Occupation numbers, Second quantization for fermions, The electron gas and the Hartree-Fock approximation, Perturbation theory, The density operator, The random phase approximation and screening , Spin Wave in the electron gas

Unit-II

Electron–phonon interactions and Superconductivity: The Frohlich Hamiltonian, Phonon energies and the Kohn effect, Polarons and mass enhancement, The attractive interaction between electrons, The Nakajima Hamiltonian. The superconducting state, BCS Hamiltonian, Bogoliubov-Valatin transformation, ground state wave function, energy gap, and the transition temperature.

Unit-III

Magnetism (Local moment magnetism, exchange interaction, Band magnetism- Stoner theory, spin density wave, Anderson model, Kondo problem); Fermi liquid theory (Electron spectral function, Quasi-particles and Landau interaction parameter, Fermi liquid in Kondo problem);

Unit-IV

Lattice Dynamics in The Harmonic Approximation; The ground state energy, The neutron scattering cross-section, The Green's function and its equation of motion, The iteration solution of G; Summation of the iteration series, The ground state energy as an integral over coupling constant, Calculation of the ground state energy and the neutron cross-section in terms of the phonon Green's function**.**

Lattice Dynamics at Finite Temperature; The free energy in the harmonic approximation, The phonon temperature Green's function temperatures, The real-time Green's function and neutron scattering.

Unit-V

The Feynman- Dyson Expansion; Zero –temperature theory: general formalism, Evaluation of the phonon Green's function at T= O by , Feynman – Dyson perturbation theory, The Feynman – Dyson expansion at finite temperatures, Direct evaluation of the free energy by Feynman- Dyson perturbation theory.

Recommended Books

1. A Quantum Approach to the Solid State, Philip L. Taylor, prentice –Hall, Inc., Englewood Cliffs, new Jersey.
2. Theory of Quantum liquid, Pines and Nozieres, West view Press.
3. Solid State Physics, by N W Ashcroft and N D Mermin, Harcourt College Publishers. (College Ed.)
4. Theory of Superconductivity. J. Robert Schrieffer, West view Press.
5. G.D. Mahan, Many-Particle Physics (Springer, Berlin, 2000).
6. S. Doniach & E.H. Soudheimer, Green's functions for Solid State Physicists, Imperial College Press, 1998.

COURSE CODE: CWDPHY- 102(b)

Name of the Course: Advanced Techniques for Materials Characterization

(Credit Weightage- 5)

Max Marks: 100 **Time: 3 hrs.**

Instructions for paper setters and candidates: *Eleven questions will be set in all. Question No. 1 section A, is compulsory covering whole syllabus of the course and consist of 10 part of short answer type question and the candidate has to attempt any 8 (eight). Question No. 2 to 10, section B, shall be set from unit 1-5. Examiner has to set 02 (two) questions from each unit, i.e., from unit-I, unit-II, unit-II, unit-IV and unit-V, respectively. Candidate has to attempt one question from each unit, i.e., total 5 (five) question from section B. Question No.1 section A will be of 40 (forty) marks and section B will be of 60 marks, each question will be of 12 (twelve) marks.*

Note: *Problem solving based questions from the topics covered in the curriculum.*

UNIT-I

Thermo-physical techniques : Differential scanning calorimetry (DSC):Principle, construction and working of DSC, effect of heating rate, effect of thermal history, effect of atmosphere, isothermal and non-isothermal conditions, observation of thermal transitions-glass transition and crystallization, calorimetry to understand structural relaxation.

Thermal thermogravimetric analysis (TGA):*Principle, construction and working of TGA, factors effect TGA-sample holder, sample mass, heating rate, furnace atmosphere.*

Unit-II

X-ray Techniques: Methods of X-ray diffraction, thin film diffraction, grazing angle x-ray diffraction, crystal structure analysis, measurements of intensities of X-ray reflection, FWHM, particle size using Scherer formula, Rietveld analysis, small angle x-ray scattering (SAXS).

Unit-III

Elemental Analysis and basic instrumentation: X—ray photoelectron spectroscopy (XPS), Energy dispersive x-ray analysis (EDX), Difference between EDX and XPS, Fourier transform infrared spectroscopy (FTIR), Ultraviolet/visible spectroscopy.

Raman spectroscopy, photoluminescence, Mossbauer spectroscopy, impedance spectroscopy, electron spin resonance (ESR), reflection high energy electron diffraction (RHEED), low energy electron diffraction (LEED).

Unit-IV

Microstructure and surface morphology: Scanning electron microscopy (SEM)-operating principle, construction and working, penetration of electrons into a solid, secondary electron image, backscattered-electron images, SEM operating parameters.

Transmission electron microscopy (TEM)-principle, construction and working, TEM imaging system,

Scanning tunneling microscopy (STM), atomic force microscopy (AFM), difference between STM and AFM.

Unit-V

Magnetic Measurements: Magnetometry – vibrating sample magnetometer (VSM), thermo-magnetic analysis, SQUID. magnetic force microscopy (MFM).

Neutron Scattering Techniques- neutron powder diffraction, single crystal neutron diffraction, magnetic neutron scattering, small angle neutron scattering (SANS).

Recommended Books

1. Material Characterization Techniques: by S. Zhang, L. Li and A. Kumar, CRC press (2009).
2. Physical Principles of Electron Microscopy: An introduction to TEM, SEM and AFM: by R.F. Egerton Springer (2005).
3. An introduction of X-ray crystallography: by M.M.Woolfson.
4. Characterization of Materials: by John B. Watchman.
5. Applications of Calorimetry, José Luis Rivera-Armenta and Cynthia Graciela Flores-Hernández, IntechOpen, UK (2022)
6. X-ray and Neutron Reflectivity: by J.Daillant and A.Gilaud (Ed) Springer (2009).

7. Fundamentals of Surface and Thin film Analysis by L.C. Feldman and J.W. Mayer published by Elsevier Science, 1986.
8. Modern Techniques for Surface Science: by D.P. Woodruff and T.A.Delchar- Cambridge University Press, 1994
9. Methods of Surface Analysis: by J.M. Walls- Cambridge University Press, 1989.
10. X-ray Fluorescence Spectroscopy: R. Jenkins – Wiley Inter science, New York, 1999.
11. The SQUID Handbook: Fundamental and Technology of SQUID and SQUID systems: by John Clarke and Alex I.Braginski, Wiley-VCH (2004).
12. Solid State Magnetism: by John Crangle &Edward Arnold- UK (1991).
13. The Principles and Practice of Electron Microscopy: by Ian. M. Walt-Cambridge University Press, 1997.

COURSE CODE: CWDPHY- 102(c)

Name of the Course: Advanced Nuclear Physics

(Credit Weightage - 5)

Max Marks: 100 **Time: 3 hrs.**

Instructions for paper setters and candidates: *Eleven questions will be set in all. Question No. 1 section A, is compulsory covering whole syllabus of the course and consist of 10 part of short answer type question and the candidate has to attempt any 8 (eight). Question No. 2 to 10, section B, shall be set from unit 1-5. Examiner has to set 02 (two) questions from each unit, i.e., from unit-I, unit-II, unit-II, unit-IV and unit-V, respectively. Candidate has to attempt one question from each unit, i.e., total 5 (five) question from section B. Question No.1 section A will be of 40 (forty) marks and section B will be of 60 marks, each question will be of 12 (twelve) marks.*

Course Outcomes:

After completion of course, students will able to

1. Explain coupling of angular momenta and concept of rotation and irreducible tensors and their use in solving nuclear physics problems
2. Understand the concept of alpha, beta and gamma nuclear decays , their kinematics and spectroscopy.
3. Explain the nuclear shell model and magic numbers, spin-orbit couplings, ground state spin of nuclei, electromagnetic moments of nuclei and second quantization techniques in shell model problems.
4. Understand the microscopic theory of nuclear structure, Hartree-Fock theory of nuclear shapes, Hartree- Fock Approximation, and able to derive the Hartree-Fock equations and calculate the single particle energies.
5. Explain the Skyrme Hartree–Fock Calculations for Finite Nuclei and calculate the binding energy, single particle energies, root mean square charge radii and charge densities with Skyrme Hamiltonian.
6. Classify and understand various types of nuclear reactions, Energetics of nuclear reactions, Coulomb scattering, Nuclear scattering, Compound-nucleus formation, direct reactions and heavy ion reactions.

Note: *Problem solving based questions from the topics covered in the curriculum.*

Unit- I

Angular Momentum: Orbital and Spin angular momentum, Total angular momentum, coupling of two angular momenta, coupling of three angular momenta, coupling of four angular momenta, Racha Coefficients

Rotation and Irreducible Tensors: Rotation, Irreducible Tensors**,** Product of tensor operators., Matrix elements of irreducible tensor operators, spherical harmonics between orbital angular momentum states, Spin operator between spin states, Angular momentum J between momentum states, Matrix elements element of compounded tensor and Matrix elements between angular momentum coupled state

Unit- II

Nuclear Decays: Alpha Decay: General Properties and theory of alpha decay, Barrier penetration of alpha decay, alpha decay spectroscopy: Branching ratios, Centrifugal barrier effects, Nuclear structure effects, Spontaneous fission, Beta Decay: General Properties, Neutrinos and Antineutrinos, Fermi theory of beta decay, Angular momentum and selection rules of beta-decay, electron capture processes, Symmetry breaking in beta decay, beta spectroscopy, Gamma decay, reduced transition probabilities for gamma decay, Weisskopf units for gamma decay.

Unit-III

Nuclear Shell Model: Single particle levels and magic numbers, Ground state spin of nuclei, Static electromagnetic moments of nuclei: magnetic moment, electric quadrupole moments of nuclei, Electromagnetic transition probability, Exact treatment of two-nucleons by Shell Model: two-nucleon wave function, matrix elements of one-body operators and two-body potential, Shell model diagonalization, Configuration mixing, use of second quantization techniques in Shell Models problems: relationship between hole state and particle state, State of hole-particle excitation and core polarization, Seniority and fractional percentage.

Unit-IV

Microscopic theory of Nuclear Structure: Hartree-Fock Theory of nuclear shapes, Hartree- Fock Approximation, Properties of single Slater determinants, Derivation of the Hartree-Fock equations, Hartree-Fock calculations and various observed quantities: Energy for state φ , deformation of state φ, single particle energies

Skyrme Hartree–Fock Calculations for Finite Nuclei: Skyrme force, Skyrme Hartree– Fock Equation, Energy Density and Determination of Parameters, Results with Skyrme Hamiltonian: binding energy, single particle energies, root mean square charge radii and charge densities.

Unit-V

Nuclear Reactions: Introduction, Types of Reactions and Conservation Laws, Energetics of Nuclear Reactions, Reaction Cross Sections, Experimental Techniques, Coulomb Scattering, Nuclear Scattering, Scattering and Reaction Cross Sections , Optical model, Compound - Nucleus Reactions, Direct Reactions, Resonance Reactions, Heavy-Ion Reactions.

Recommended Books

1. Theory of Nuclear Structure, M. K. Pal, Affiliated East-West Press Pvt. Ltd. , Madras-1992.
2. The Nuclear Shell Model, K. L. G. Heyde, (Springer-Verlag, 1994)
3. Basic Ideas and Concepts in Nuclear Physics: An Introductory Approach, K. Heyde
4. Angular Momentum in Quantum Mechanics, A. R. Edmonds, (Princeton University Press, 1957
5. P. J. Brussaard and P. W. M. Glaudemans, Shell Model Applications in Nuclear Spectroscopy, (North Holland, 1977).
6. D. M. Brink and G. R. Satchler, Angular Momentum, (Clarendon Press, Oxford, 1968).
7. INTRODUCTORY NUCLEAR PHYSICS, Kenneth S. Krane, JOHN WlLEY & SONS.
8. An Introduction to Nuclear Physics, W. N. COTTINGHAM & D. A. GREENWOOD, Cambridge University Press.
9. Concepts of Nuclear Physics, Bernard L. Cohen, McGraw-Hill

Other Suggested Material

1. D. Vautherin and D. M. Brink, Phys. Rev. C 5, 626 (1972).
2. T. R. H. Skyrme. Philos. Mag. 1, 1043 (1956); Nucl. Phys. 9, 615 (1959); 9, 635 (1959).
3. W. Kohn and L. J. Sham, Phys. Rev. 140 A1133 (1965).

COURSE CODE: CWDPHY- 102(d)

Name of the Course: Advanced Nuclear Astrophysics

(Credit Weightage - 5)

Max Marks: 100 **Time: 3 hrs.**

Instructions for paper setters and candidates: *Eleven questions will be set in all. Question No. 1 section A, is compulsory covering whole syllabus of the course and consist of 10 part of short answer type question and the candidate has to attempt any 8 (eight). Question No. 2 to 10, section B, shall be set from unit 1-5. Examiner has to set 02 (two) questions from each unit, i.e., from unit-I, unit-II, unit-II, unit-IV and unit-V, respectively. Candidate has to attempt one question from each unit, i.e., total 5 (five) question from section B. Question No.1 section A will be of 40 (forty) marks and section B will be of 60 marks, each question will be of 12 (twelve) marks.*

Course Outcomes:

After completion of course, students shall be able to :

1. Explain the observational basis of nuclear astrophysics, stellar evolution, r, s and processes in the nucleosynthesis of elements.
2. Discuss concept of general relativity, Einstein and Tolman–Oppenheimer–Volkoff Equations for the structure of star.
3. Explain matter in β -Equilibrium, properties of Free Fermi Gases, polytropic equation of state, hydrostatic stability and Lane-Emden equation, structures of white dwarfs, Chandrasekhar mass.
4. Understand dense matter in compact star, composition of stars, novel phases of dense matter, hyperons, non-relativistic and relativistic models of dense matter, hybrid stars.
5. Understand the concept of gravitational Waves, Detection of Gravitational Waves, Neutron Star Mergers, Gravitational Wave Emission from Binary Systems, Tidal Deformability, Dark matter/energy, Cosmic microwave background.

Note: *Problem solving based questions from the topics covered in the curriculum.*

Unit-I

General aspects of Astrophysics: Introduction to stellar evolution, Hydrostatic Hydrogen burning: pp chains, CNO cycles, Hydrostatic Hydrogen burning beyond the CNO mass regions, Helium burning reactions, Nucleosynthesis during Hydrostatic He Burning, Advanced burning stages: C, Ne, O, Si burning, Explosive burning in core-collapse supernovae, Nucleosynthesis beyond the Iron peak: s- Process, r- Process , p- process, Big Bang Nucleosynthesis

Unit-II

General Relativity: Gravity and the Equivalence Principle, Special Relativity and the Metric, Einstein's Equation, The Schwarzschild Metric, Energy-Momentum Tensor, The Full Einstein Equation with Matter, Tolman–Oppenheimer–Volkoff Equation, The Schwarzschild Solution for a Sphere of Fluid

Unit-III

Dense Matter: Thermodynamic Potentials, Chemical Equilibrium, Matter in β -Equilibrium, Equation of State, Properties of Free Fermi Gases, Polytropes, White Dwarfs: Degenerate pressure of electrons, polytropic equation of state, hydrostatic stability and Lane-Emden equation, structures of white dwarfs, Chandrasekhar mass.

Unit-IV

Compact Stars: Discovery of neutrons and Landau's prediction of neutron stars in 1932, measurement of masses and radii of neutron stars, Pulsars and Magnetars, neutron star cooling and superfluidity, Dense Matter in Neutron Star: Composition of neutron stars, novel phases of dense matter, Hyperon, Bose condensate, quark matter and Equation of state, Non-relativistic and relativistic models of dense matter, masses and radii of neutron stars, Quark stars, Hybrid stars.

Unit-V

Gravitational Waves: Elementary introduction to Gravitational Waves, Linearized Gravity and Gauge Transformations, Production of Gravitational Waves: Energy of Gravitational Waves, Energy Loss Due to Gravitational Radiation, Einstein's Quadrupole Formula, Detecting Gravitational Waves, Ellipticity of Neutron Stars, Neutron Star Mergers: The Chirp Mass, Gravitational Wave Emission from Binary Systems, Tidal Deformability, Dark matter/energy, Cosmic microwave background, gamma -ray bursts.

Recommended Books

1. Nuclear Physics of Stars, Christian Iliadas, Wiley –VCH Verlay GmbH & Co. 2007
2. Compact Star Physics, Jürgen Schaffner-Bielich, Cambridge University Press (2020).
3. Principles of Stellar Evolution and Nucleosynthesis. Donald D. Clayton, The University of Chicago Press.
4. The Early Universe, E.W. Kolb and M. S. Turner Addison-Wesley Publication company
5. Compact Stars: Nuclear Physics, Particle Physics and General Relativity, Norman K. Glendenning, Springer 2nd Edition.

COURSE CODE: CWDPHY- 102(e)

Name of the Course: Advanced Particle Physics

(Credit Weightage - 5)

Max Marks: 100 **Time: 3 hrs.**

Instructions for paper setters and candidates: *Eleven questions will be set in all. Question No. 1 section A, is compulsory covering whole syllabus of the course and consist of 10 part of short answer type question and the candidate has to attempt any 8 (eight). Question No. 2 to 10, section B, shall be set from unit 1-5. Examiner has to set 02 (two) questions from each unit, i.e., from unit-I, unit-II, unit-II, unit-IV and unit-V, respectively. Candidate has to attempt one question from each unit, i.e., total 5 (five) question from section B. Question No.1 section A will be of 40 (forty) marks and section B will be of 60 marks, each question will be of 12 (twelve) marks.*

Course Outcomes:

After completion of course, students will able to

1. Explain symmetries and conservations laws, SU(2) group and Flavour SU (3) and neutron kaonsystem.
2. Understand the formulation of Standard model, concept of quantum chromdynamics and quarkgluon plasma.
3. Understand the concept of Higgs mechanism in standard model, Fermion masses, Cabbibo-Kobayashi-Maskawa matrix, neutrino oscillations, helicity of the neutrino, neutrino mass terms of Dirac and Majorana type, the neutrino mixing matrix.
4. Explain the SU(5) model and Grand Unification Theory, Fermion representations, spontaneoussymmetry breaking in SU(5), SO(10) grand unified theory, Fermion masses in SO(10).
5. Explain the Poincare group and Supersymmetry, two component Weyl Spinors, String theory and duality.
6. Understand various concepts such as accelerating Universe and dark energy, modified gravity,and thermal history of the Universe.

Note: *Problem solving based questions from the topics covered in the curriculum.*

Unit-I

Symmetries and conservation laws in Physics, Charge conjugation, time reversal invariance, parity, G-parity, symmetries and groups, SU(2) group, isospin, combining representations, Flavour SU(3), quark model, τ-θ puzzle, parity violation, CP-violation: the neutral kaon system, CPT theorem

Unit-II

Formulation of the Standard Model: Introduction, Quarks and Leptons, Quark Content of Mesons, Quark Content of Baryons , Need for Color , Quark Model for Mesons, Valence and Sea Quarks in Hadrons, Weak Isospin and Color Symmetry, Gauge Bosons, Dynamics of the Gauge Particles, Symmetry Breaking, Quantum Chromodynamics (QCD) and Confinement, Quark-Gluon Plasma

Unit-III

Standard model of fundamental interactions, construction of SU(2)XU(1) theory, spontaneous symmetry breaking and Higgs mechanism in standard model, Fermion masses, GIM mechanism, Cabbibo-Kobayashi-Maskawa (CKM) matrix, Quark mixing and CP-violation, Color gauge invariance and QCD, neutrino oscillations, helicity of the neutrino, neutrino mass terms of Dirac and Majorana type, neutrino masses in SU(2)XU(1) theory, the neutrino mixing matrix.

Unit-IV

Idea of Grand Unification, choice of the gauge group, SU(5) model of grand unified theory, generators of SU(5), Fermion representations, spontaneous symmetry breaking in SU(5), SO(10) grand unified theory, Fermion masses in SO(10), neutrino masses in SO(10).

Unit-V

Poincare group and Supersymmetry: Introduction, Poincare group, two component Weyl Spinors, Spinor algebra and Supersymmetry, Supersymmetric multiplets, Super symmetry and Strings, String theory and duality: M-theory, The Standard Model of Cosmology, Accelerating Universe and dark energy: evidence from supernovae and CMB data, Quintessence, modified gravity, Hot Big Bang: Thermal history of the Universe.

Recommended Books

1. Particle Physics: An Introduction, M. Leon (Academic Press).
2. A Modern Introduction to Particle Physics, Fayyazuddin and Riazuddin, Third Edition, World Scientific.
3. Introduction to Nuclear and Particle Physics, A Das and T. Ferbel, Second Edition, World Scientific.
4. Quarks and Leptons: An introductory course in Modern Particle Physics, Francis Halzen and Alan D. Martin (John Wiley & Sons).
5. Gauge Theory of Elementary Particle Physics, Ta-Pei Cheng and Ling Fong Li (Clarendon Oxford).
6. Gauge, Theories of Strong, Weak and Electromagnetic Interactions, C. Quigg (Addison – Wesley).
7. Grand Unified Theories, Graham G. Ross (Oxford University).
8. Neutrino Physics, Kai Zuber (CRC Press, Taylor and Francis Group).
9. Physics of Neutrinos and Applications to Astrophysics, M. Fukugita and T. Yanagida (Springer).
10. Massive Neutrinos in Physics and Astrophysics, Rabindra Mohapatra (World Scientific).