ANDHRA UNIVERSITY

DEPARTMENT OF NUCLEAR PHYSICS

PROGRAM : M.SC. NUCLEAR PHYSICS

SCHEME AND SYLLABUS

EFFECTIVE FROM 2020-2021 BATCH

ANDHRA UNIVERSITY
DEPARTMENT OF NUCLEAR PHYSICS
CURRICULAM FOR M.Sc. (**NUCLEAR PHYSICS**) PROGRAMME
EFFECTIVE FROM 2020 –21ADMITTED BATCH

Semester	Name of the Paper	Max. Marks	Grade Point
Semester I			
Paper 101	Mathematical methods of Physics	100	4
Paper 102	Classical Mechanics	100	4
Paper 103	Electrodynamics	100	4
Paper 104	Electronic Devices and circuits	100	4
Paper 105	Electronics Practical-I	100	4
Paper 106	Modern Physics Practical-I	100	4
Semester II			
Paper 201	Atomic and Molecular Physics	100	4
Paper 202	Quantum Mechanics -I	100	4
Paper 203	Statistical mechanics	100	4
Paper 204	Condensed matter Physics	100	4
Paper-205	Electronics Practical-II	100	4
Paper-206	Modern Physics Practical-II	100	4
Semester III			
Paper 301	Quantum Mechanics -II	100	4
Paper 302	Nuclear and Particle Physics	100	4
Paper 303	Nuclear Radiation Detectors, Data Acquisition and Analysis	100	4
Paper 304	Computational Methods and Programming	100	4
Paper 305	Nuclear Physics Practical-I	100	4
Paper 306	Computer Programming Lab-I	100	4
Paper 307	MOOCs paper/program (with external agency)		2
Paper 308	Value added/ skill development (with external agency)		2

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Semester IV

Paper 401	Nuclear Reactions and Particle Accelerators	100	4
Paper 402	Reactor Physics	100	4
Paper 403	Nuclear Spectroscopy	100	4
Paper 404	Nuclear Techniques in material Science & Radiation Physics	100	4
Paper 405	MOOCs paper/program (with external agency)		2
Paper 406	Value added/ skill development (with external agency)		2
Paper 407	Project	200	8
Paper 408	Comprehensive Viva-Voce	100	4

Program Outcomes:

PO1:Learn physical concepts through mathematical applications along with some mathematical topics

PO2: Gain knowledge of theoretical as well as practical uses of semiconducting devices

PO3: Understand condensed matter related theoretical phenomena in addition to some practical studies

PO4: Obtain skills of program(s) writing in 'C' languages and application of them to mathematical computations in the form of theory as well as practical mode

PO5: Study about physics of atoms and molecules besides variety of other particles and their detection

PO6: Acquire knowledge pertaining to different detection system of nuclear particles and radiation

PO7: Learn in depth about nucleus and its various physical concepts of an atom

PO8: Understand functioning of different nuclear techniques, their applications in research and industry

PO9:Study regarding nuclear reactor physical concepts and their practical uses and nuclear power development

PO10:Gain hands on experience in the detection of some of the nuclear particles and photons, evaluate their physical concepts

Program Specific Outcomes:

PSO1: Understand theoretical phenomena as well as practical applications of physical concepts

PSO2: Learn more about physical concepts of nucleus facilitating to understand in depth about atomic energy

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PSO3: Understand more about variety of nuclear techniques; their functioning and practical applications of them
PSO4: Study about neutron, nuclear reactor, and nuclear power generation

Program Learning Outcomes:

1. Students can pursue higher education in India (MTech) or in abroad (MS)
2. After completion of degree at higher level, can become scientist in R & D organizations
3. Can be employed in the institutions and organization that use radio isotopes for application purpose
4. Candidates may be pursed research program leading to PhD degree
5. Successful candidates can enter into teaching profession in higher educational institutions
6. With the learned logical thinking and reasoning, one can write competitive exams for getting employment

Program Specific Learning Outcomes:

1. Highly talented candidates can obtain employment in DAE institutions
2. organizations related to applied nuclear science such as cancer hospitals (Radiation physicist), food preservation with radio isotope techniques, materials irradiation industriesRadiation provide employment
3. Employment can be obtained as radiation safety officer (RSO), Non-destructive technician in the fuel and material industries etc
4. Candidates are eligible to work in nuclear power industries

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SEMESTER – I PAPER – 101 MATHEMATICAL METHODS OF PHYSICS

Unit-I:

Special Functions: (Without Power Series Solutions),Beta and Gamma Functions: Definition and Simple Properties, Bessel Functions of the first kind: Generating Function, Recurrence Relations, Differential Equation satisfied by Bessel functions, and Integral representation.

Unit-II:

Hermite, Laguerre And Legendre Polynomials: Generating Functions, Recurrence Relations, Rodrigue's Formulae, Orthogonality and Normalisation properties, and Differential Equations satisfied by these Polynomials, Associated Legendre Polynomials and Spherical Harmonics

Reference:

Mathematical Methods for Physicists G. Arfken: Ch 10. sec10.1,.4; Ch 11 sec11.1; Ch 12 Sec12.1,.2,.3,.5,.6; Ch 13 sec13.1,.2

Unit-III:

Laplace Transforms: Definition and Simple properties of Laplace Transforms
Laplace transforms of Elementary functions, Laplace transforms of Derivatives, Inverse Laplace Transform, Applications of Laplace Transforms

Reference: Mathematical Methods for Physicists by G. Arfken Ch 15 Sec 1,7,8,9,11,

Unit-IV:

1. Functions of Complex Variable: Analytic Functions, Cauchy-Riemann Conditions,

Cauchy's Fundamental theorem, Cauchy's Integral Formula, Taylor's series, Laurent's series, Singularities, Classification of Singularities, Cauchy's Residue Theorem, Application of Residue Theorem to evaluate simple Contour Integrals.

Reference: Functions of Complex Variable with applications E. G. Phillips Ch 1 sec5,6,7; Ch 4 sec30 to 36; Ch 5 Sec 43 to 46

Unit-V:

Tensor Analysis: Concepts of Tensor, Contravariant, Covaririent and Mixed Tensors, Addition and Subtraction of Tensors, Contraction of a Tensor, Outer product and inner product of two tensors, Quotient law,

Reference: Tensor Calculus by Barry Spain, Chapter-1 Sections 1 to 13

<u>Course outcomes:</u>

1. Gain knowledge related to usage of different special functions to understand the general physics.
2. Improves logical thinking and is intended to give mathematical tools necessary for better understanding of later courses in physics such as classical

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electrodynamics, quantum Mechanics, statistical mechanics, solid state physics.

3. Learns to apply Laplacetransformationstophysics problems, which is a pre requisite for deeper understanding of theoretical concepts such as classical and Quantum mechanics.
4. Obtain knowledge how to convert one system into another system.
5. Facilitate to understand different types of co-ordinate systems to solve equations of motion in classical as well as Quantum systems.

<u>Course specific outcomes:</u>

1. Learns Mathematical tools for application to understand different physical systems
2. Gain knowledge of logical thinking to interpret physical concepts with theoretical processes

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SEMESTER – I PAPER-102 CLASSICAL MECHANICS

Unit:I

Mechanics of a Particle, Mechanics of system of particles, Constraints, D'Alembert's Principle and Lagrange's Equations, Application of Lagrangian Formalism.

Hamilton's Principle, Calculus of Variations, Lagrange's equations from Hamilton's Principle, Hamilton's Principle for Nonholonomic Systems, Conservation Theorems, Energy function and Conservation of Energy.

Hamilton's equations of motion: Legendre Transformations and Hamilton equations of Motion. Cyclic Coordinates and conservation Theorems. Hamilton's equations from a Variational Principle. Principle of Least Action.

Unit:II

Canonical Transformations: Equations of Canonical Transformation. Examples. Harmonic Oscillator. Poisson Brackets, Infinitesimal Canonical Transformations. Conservation Theorems in Poisson Bracket Formalism. Angular Momentum Poisson Bracket Relations. Liouville's Theorem.

Central Force Problem: Reduction of two-body problem into one-body problem, Equations of motion and first integrals, Equivalent one-dimensional problem, Classification of orbits, Virial Theorem, The differential equation for the orbit, Bertrand's theorem, Kepler Problem: Inverse square law of force, Motion in Time in Kepler Problem, Scattering in a Central Force field, transforming the scattering problem to Laboratory coordinates, Three-body Problem.

Unit:III

Kinematics of Rigid Body Motion: Independent Coordinates of a Rigid Body, Orthogonal Transformations, Formal Properties of Transformation Matrix, Euler Angles, Cayley-Klein Parameters, Euler's Theorem for Rigid Body motion, Finite Rotations, Infinitesimal Rotations, Coriolis effect.

Equations of motion of Rigid Body: Angular momentum and Kinetic Energy of Motion about a Point, Tensors, Inertia Tensor and Moment of Inertia, Solving Rigid Body Problems and Euler equations of motion, Torque free motion, Heavy symmetric top with one point fixed, Precession of equinoxes and Satellite orbits, Precession of system of charges in a magnetic field.

Unit:IV

Hamilton-Jacobi Theory and Action–Angle Variables: Hamilton-Jacobi equation for Hamilton's Principal Function. Harmonic Oscillator Problem. Hamilton-Jacobi equation for Hamilton's Characteristic function. Separation of Variables in Hamilton-Jacobi equation. Ignorable coordinates and the Kepler Problem. Action-angle variables in systems of one degree of freedom. Action-angle variables for completely separable systems. Kepler Problem in Action-angle variables.

Unit:V

Classical Mechanics of Special Theory of Relativity: Postulates of Special Theory, Lorentz Transformations, Velocity Addition and Thomas Precession, Vectors and Metric Tensor, Forces in Special Theory: Electromagnetism, relativistic kinematics of Collisions and many particle systems, Introduction to General Theory of Relativity.

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References: Classical Mechanics (3rd Edition) Chapters 1,2,3,4,5,7,8,9,10 by Herbert Goldstein, Charles P. Poole and John L. Safko

Course outcomes:

1. Obtain the knowledge about particles in macro systems facilitating different solutions of mechanical systems that are in motion
2. Understand how to reducemany body systems as one body systems by using various mathematical methods
3. Analyse the motion of rigid body with respect to various degrees of freedom.
4. Learns about angular movement of bodies
5. Improve logical thinking relating to relative motion of bodies

Course specific outcomes:

1. Study classical mechanics physical concepts such as angular momentum, rigid body etc
2. Acquire skills of motion and mechanics of many body systems

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3. SEMESTER – I PAPER-103ELECTRODYNAMICS

Unit 1

Maxwell's equations: Maxwell's Equations in Free Space and Linear isotropic media. Boundary conditions on the fields at interfaces

(Scope: DJG, Ch.7, Sec.3 and JDJ: Ch.1 Sec5)

Potential formulation of electrodynamics: Scalar and Vector potentials, Gauge transformations - Coulomb gauge, Lorentz gauge, Gauge invariance, Lorentz force law in potential form. Poynting's theorem, Maxwell's Stress Tensor, Conservation of Energy and Momentum

(Scope: DJG, Ch.8, Sec.1, 2, Ch.10 Sec1. And JDJ: Ch.6, Sec1, 2, 3, 7)

Unit 2

Covariant Electrodynamics: Invariance of Charge, Covariant form of Lorentz condition and Wave equations - Equation of Continuity - Maxwell's equations - Transformation of Electromagnetic fields - Electromagnetic Field Tensor in Four Dimensions. Dual Field Tensor

(Scope: DJG, Ch.12, Sec.3 and GKS, Ch.12, Sec.6 to 10. And JDJ: Ch.11 Sec 9, 10)

Unit 3

Electromagnetic waves: The Wave Equation, Electromagnetic waves in non-conducting media- Plane waves in Vacuum - Energy and Momentum of electromagnetic waves - Propagation through Linear media – Polarization Reflection and Transmission at a Conducting surface/thin layer. Dispersion - The frequency dependence of Permittivity, Permeability and Conductivity – Dispersion in non-conducting media-Cauchy's Equation.

(Scope: DJG, Ch.9, Sec.1,2,3,4 and GKS, Ch.7, Sec.1,2,3,5: Ch.8, Sec.1,2,4,7,19.)

Unit 4

Fields and Radiation by Moving Charges: Retarded Potentials - 'Lienard-Wiechert Potentials' – Electric and Magnetic fields due to a uniformly moving point charge and an accelerated charge. Power radiated by accelerated charge - Larmour's formula and its relativistic generalisation - Radiation losses in charged particle accelerators. Electric and Magnetic dipole radiation. Linear and Circular acceleration and angular distribution of power radiated, Bremsstrahlung, Synchrotron radiation and Cerenkov radiation, Radiation reaction force.

(Scope: DJG, Ch.10, Sec. 1, 2, 3 Ch.11 Sec 1, 2 and GKS, Ch.10, Sec.7,8. And JDJ: Ch.13 Sec4, Ch.14 Sec 1, 2, 6, Ch.15 Sec 2, Ch.16 Sec 2, 3)

Unit 5

Electrodynamics of charged particle in Electromagnetic fields: Lagrangian and Hamiltonian for a Relativistic charged particle in external electromagnetic fields. Motion in a uniform, Static, Magnetic field. Lowest order Relativistic corrections to the Lagrangian for interacting charged particles, the Darwin Lagrangian. Lagrangian for the electromagnetic fields. ProcaLagrangian, Photon mass effects.

(Scope: JDJ, Ch.12, Sec.1,3,7,8,9.)

Wave Guides: Propagation of waves between conducting Conducting Planes, Waves in guides of Arbitrary cross section, Wave guides of rectangular cross section,

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Coaxial Wave Guide, Resonant cavities, Dielectric wave guides
(Scope: BB Laud, Ch.8, Sec.1,2,3,4,5,6.)

Text and Reference Books:

1. DJG: David J.Griffiths:'Introduction to Electromagnetics'. 3rd Edition. Pearson Education Asia.
2. JDJ: J.D. Jackson: 'Classical Electromagnetics'. 3rd Edition 2005. John Wiley &sons, Inc.
3. GKS: Gupta, Kumar and Sharma: 'Foundations of Electromagnetic Theory'. Addison-Wesly
4. B.B. Laud: 'Electromagnetics'. Wiley Eastern Ltd.

Course Outcomes:

1. Learns the concepts of electrodynamics, Maxwell equations, boundary conditions and potential formulation scalar and vector potentials
2. Understand the basic principles of light propagation, Transmission, Reflection, Refraction diffraction and Polarization.
3. Formulate and solve electrodynamic problems in relativistically covariant form in four-dimensional space and time.
4. Calculate the electromagnetic radiation from localized charges which move arbitrarily in time and space, taking into account retardation effects.
5. Calculate the electromagnetic radiation from radiating systems relativistically and non relativistically taking into account retardation effects.

Course specific outcomes:

1. Formulate self-consistent models for the interaction between matter and electromagnetic fields in relativistically covariant Lagrange and Hamilton formalism
2. Understand photons propagation properties through matter

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SEMESTER – I PAPER –104 ELECTRONIC DEVICES AND CIRCUITS

Unit 1

Network theorems: - Thevenin theorem, Norton's theorem and maximum power transfer theorem. Semiconductor Devices: - Tunnel diode, Photo diode, Solar cell, LED, Varactor diode, silicon controlled Rectifier, Photo Transistor.

UJT- characteristics and relaxation oscillator. JFET and MOSFET – construction and characteristics – and their applications. JFET as common source amplifier.

Unit 2

BJT – CE amplifier – voltage gain, input and output resistance, graphical analysis and analysis using h-parameter equivalent circuit.

Feedback Amplifiers: Feedback concept, types of feed back, general characteristics of negative feedback in amplifiers, voltage series feedback, current series feed back and voltage shunt feedback.

Unit 3

Digital Electronics: (Combinational Logic) The transistor as a switch, OR, AND and NOT gates – NOR and NAND gates – Ex OR gate. Boolean algebra and Logic implementation. Decoders and Encoders, Multiplexers and De multiplexers.

Digital Electronics: (Sequential Logic) Flip-Flops, one bit memory – RS flip-flop, JK flip-flop, JK – master slave flip-flop, T flip-flop. Modulo N counters.

Unit 4

Operational Amplifiers: Ideal Operational amplifier. Op. Amp. Architecture - differential stage, gain stage, dc level shifting and output stage. Practical inverting and Non inverting Op. Amp configurations, voltage follower.

Op. Amp parameters – input offset voltage (Vio) input bias current (Iio), Output offset voltage, Common Mode Rejection Ratio (CMRR), Slew rate, Op. Amp. Open loop gain

Unit 5

Op. Amplifier applications:- Summing, scaling and difference of input voltages, Integrator and Differentiator. RC phase shift Oscillator. Comparators. Window - comparator, Schmitt trigger

Voltage regulators – fixed regulators and adjustable voltage regulators. Classification of Oscillators, colpitts Oscillator, Hartley Oscillator, Wien Bridge Oscillator, crystal Oscillator, Astable, Bistable and Monostable multivibrators.

Text and Reference Books:

1. "Basic Electronics (solid state)" B.L.Theraja
2. "Electronic devices and circuits" Theodore F. Bogart, Jr.
3. "Electronic devices and circuits" Allen Mottershead.
4. "Digital principles and Applications" - A.P. Malvino and D.P. Leach.

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Course Outcomes:

1. Ability to apply basic concepts of Inorganic and Organic Semiconductor materials for electronic device application in modern electronic industry applications like LCD's, LEDs and solar cells.
2. Understanding the Transistor characteristics using BJT, UJT, JFET and MOSFETs
3. Understand the transistor as multivibrators and concept of negative feedback in amplifiers: voltage [series, shunt], current [series, shunt]
4. Understand the basic working of different logic gates and laws of Boolean algebra, De Morgan theorem, NOR & NAND logic for simplification of circuits.
5. Understand different digital storage devices, memory, their classification, analyzing the different parameters of OP-AMP and applications Op-Amp

Course specific outcomes:

1. Understand various semiconducting devices, their functioning and application in electronic applications
2. Gain the knowledge of logical gates and digital electronics

Mapping of course comes with program outcomes (Semester-I)

Course outcomes	CO-1	CO-2	CO-3	CO-4
Program out comes (PO& PSO)	PO1- PSO1	PO1- PSO1	PO1- PSO1	PO1- PO2 PSO1

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SEMESTER – II PAPER – 201 ATOMIC AND MOLECULAR PHYSICS

Unit 1

Spectra of alkali elements- Different series in alkali spectra, Ritz combination principle, Spin-orbit interaction, Doublet structure in alkali spectra, transition rules, intensity rules.

Spectra of alkaline earths, Coupling schemes, interaction energy levels in L-S coupling and J-J coupling, Term series and limits in two electron systems, selection rules in atoms of two valence electrons, singlet and triplet series in two valance electron systems, Two electrons atom – He atom, Spectrum of helium atom.

Unit 2

Fine and hyperfine structure of spectral lines: fine structure of hydrogen lines, Lamb shift, experimental determination of Lamb shift, hyperfine structure—experimental study and interpretation, measurement of nuclear spin, the width of spectral line.

Effect of electric and magnetic fields on the spectrum of an atom: Zeeman effect—classical interpretation of Normal Zeeman effect, Vector atom model and normal Zeeman effect, Vector atom model anomalous Zeeman effect, Paschen – Back effect, quantam mechanical treatment of Zeeman and Paschen-Back effect, Lande's g-factor for two valance electron system—L-S coupling and j-j coupling, Stark effect, Linear Stark effect (Hydrozen Atom), Quadratic Stark effect.

Unit 3

Types of Molecular energy States and Molecular Spectra: Separation of Electronic and Nuclear Motion: The Born Openheimer approximation, Types of Molecular Energy states and associated spectra, regions of the spectrum, Pure rotational spectra—salient features of rotational spectra, the molecule as a rigid rotator, diatomic molecule as a non rigid rotator, determination of bond length and moment of inertia, isotopic effect in rotational spectra,

Unit 4

Vibrational - Rotational spectra—Vibrating diatomic molecule as a Harmonic oscillator and Anharmonic Oscillator, Fine structure of Infra red Bans, fine structure of rotation-vibration bands, Isotope effects in vibrational bands, Applications of Vibrational Spectroscopy Electronic transitions and Frank-Condon principle, Electronic spectra in emission and absorption, vibrational coarse structure.

Unit 5

Raman spectra—classical and quantum theory of Raman effect, Vibrational Raman spectra, Pure rotational Raman spectra, vibrational-rotational Raman spectra, structure determination from Raman &infra red spectroscopy.

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Scope: Elements of Spectroscopy by Gupta, Kumar & Sharma
Section-I Cha. 6 Sec. 1, 2,4,5,6,7,12,13,14,17 & 19
Section-I Cha. 7 Sec. 1,2,5,7,9 & Cha. 9 Sec. 1,2,3,4,5,6,7,11,12
Text and Reference Book: Introduction to Atomic Spectra by H.E. White, McGraw Hill Publ.

Scope: Elements of Spectroscopy by Gupta, Kumar & Sharma
Section IV 1.2, 2.1, 2.2,2.3, 3.1,3.3, 3.4, 5.1,5.2.
Section IV 4.0,1,2,3,4.
Text and Reference Book:
Fundamentals of Molecular Spectroscopy, C.N. Barwell, Tata-McGraw Hill.

Course Outcomes:

1. Understanding the atomic spectra of one and two valance electron atoms.
2. Understanding the change in behaviour of atoms in the applied external electric and magnetic field.
3. Describe electron spin and nuclear magnetic resonance spectroscopy and their applications.
4. state and justify the selection rules for various optical spectroscopies in terms of the symmetries of molecular vibrations
5. Knowledge on rotational, vibrational, electronic and Raman spectra of molecules. Structure determination molecules from Raman spectrometry

Course Outcomes:

1. Learns physics of atoms when subjected to magnetic and electrical fields
2. Obtain knowledge of molecular spectroscopy

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SEMESTER – II PAPER – 202QUANTUM MECHANICS - I

Unit:I

Introduction: Wave particle duality – physical significance of the wave function – wave packets – states with minimum uncertainty product – time evolution of the system – superposition principle – wave function of a particle having definite angular momentum – Heisenberg's uncertainty principle – complementary principle.(B.J.: Ch. 2; G.K.S.S.: Ch.2)

Formalism of quantum mechanics: state of the system – dynamical variables and operators – adjoint of an operator – Hermitian operators – properties of Hermitian operators – derivation of Heisenberg's uncertainty principle. (B.J.: Ch. 5 Sec.1-4,7; G.K.S.S.: Ch. 8.10,10-1to14)

Unit:II

Schrodinger's wave equation: time dependent Schrodinger's wave equation – conservation of probability – continuity equation – expectation values of dynamical variables – Ehrenfest's theorem – time independent Schrodinger's wave equation – stationary states – admissible wave functions – energy quantisation – properties of eigen functions – Dirac's delta function. (B.J.: Ch. 3 Sec.1-6, Appendix A; G.K.S.S.: Ch. 2) Applications of time independent Schrodinger's wave equation to one-dimensional problems: free particle – potential step – potential barrier – infinite square well – linear harmonic oscillator. (B.J.: Ch. 4; G.K.S.S.: Ch. 4.1,5-9)

Unit:III

Angular momentum and quantum mechanics: orbital angular momentum – commutation relation for orbital angular momentum – eigen values and eigen functions of L_Z and L^2 – rigid rotator. Elementary theory of spin angular momentum: spin angular momentum – spin magnetic moment and spin orbit interaction – Pauli's spin matrices. (B.J.: Ch. 6 Sec.1-4,8; G.K.S.S.: Ch. 8.16, 10-6 to10, 12.1to 5)

Unit:IV

Time independent perturbation theory: non degenerate states and degenerate states – application to linear Stark effect. Variational method – ground state energy of the hydrogen atom – helium atom. W.K.B. method – barrier penetration – alpha decay. (B.J.: Ch. 8 Sec.1-4; G.K.S.S.: Ch. 9.1-5.1 (B))

Unit:V

Applications of time independent Schrodinger's wave equation to three-dimensional problems: free particle – separation of Schrodinger's wave equation in Cartesian co-ordinates – three-dimensional harmonic oscillator – central potentials – separation of Schrodinger's wave equation in spherical polar co-ordinates – hydrogen atom. (B.J.: Ch. 7 Sec.2, 5 and 16; G.K.S.S.: Ch.5.1,6 and 11)

References : (1) Introduction to Quantum Mechanics - B. H. Bransden and C. J. Joachain
(2) Quantum Mechanics - Gupta, Kumar and Sharma

Additional References:

1. Quantum Mechanics – L.I. Schiff.
2. Quantum Mechanics – A.P. Messaiah
3. Quantum Mechanics – E. Merzbacher
4. Quantum Mechanics – A.K. Ghatak and S. Lokanadhan and

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5. A Text Book of Quantum Mechanics – P.M. Mathews and K. Venkatesan.

Course Outcomes

1. To study the basic principles of quantum mechanics
2. Learn how to solve the Schrödinger’s equations for spin less particles moving in the one-dimensional potentials
3. To understand the concepts of angular momentum and operator formulation in quantummechanics
4. Learn how to solve the Schrödinger’s equations for particles moving in three dimensional potentials
5. To impart knowledge about the approximation methods that deals with solving the problems inone dimensional and three-dimensional potentials

Course specific Outcomes

1. Able to treat molecules quantum mechanically and able to apply semi-classical method totreat atom field interactions
2. Understand the central concept and principles of relativistic Quantum mechanics

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SEMESTER – II PAPER – 203 STATISTICAL MECHANICS

UNIT-I

General principles and Foundations of statistical mechanics: Introduction to statistical mechanics – Probability – Distribution of n molecules in two halves of a box – phase space - Ensembles – Density of distribution in the phase space – Liouville's Theorem – Statistical equilibrium – Micro states and Macro states – Maxwell Boltzmann distribution law – Entropy and Probability

UNIT-II

Partition Functions (Method of Ensembles): Introduction – Microcanonical ensemble – Entropy in statistical mechanics – Conditions for equilibrium – Connection between statistical and thermodynamic quantities – Partition function – Entropy of a perfect gas (Ideal gas) – Gibb's paradox, Gibb's Canonical Ensemble. Equipartition theorem – Comparison of various Ensembles - separation of Partition functions - Partition function and thermodynamic properties of diatomic molecules – Theory of imperfect gases: Virial coefficients – Determination of Virial coefficients

UNIT-III

Quantum Statistics: Introduction – The density matrix – Bose Einstein statistics – Fermi–Dirac statistics – Maxwell Boltzmann statistics – Results and comparison of three statistics –Black body radiation and Planck's distribution law. Bose Einstein gas: MB distribution as a limiting case of BE distribution; Degeneracy and BE condensation–Fermi–Dirac gas - degeneracy - Thermodynamic properties of degenerate Fermi–Dirac gas – Electron gas in metals – Specific heat anomaly in metals and its solution – Quantum theory of diatomic molecules – Principle of detailed balance.

UNIT-IV

Specific Heats: - Specific heat of solids – Dulong and Petit's law – Einstein's theory of specific heat – Debye's theory Specific heat of a solid

Fluctuations: Introduction – Mean-square deviation – Fluctuations in ensembles – Random walk and Brownian motion – Electrical noise (Nyquist theorem) - Ising model – Bragg – Williams's approximation – One dimensional Ising model

UNIT-V

Special topics in Statistical Mechanics: Low temperature physics: - Introduction – Production of low temperatures – Approach to absolute Zero by adiabatic demagnetization – Measurement of low temperatures – Conversion of magnetic temperature to Kelvin temperature - Helium I and II – Some peculiar properties of helium II – Attempted explanations of Helium II.

Text and Reference Books:

1. **Fundamentals of Statistical and Thermal Physics by F. Reif**
2. **Thermodynamics, Statistical physics &Kinetics by Satya Prakash & J.P. Agrawal**
3. **Statistical Mechanics by B.K. Agrawal & M. Eisner**

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Course outcome (2nd semester)

1. Facilitate to develop logical thinking due to particles distribution of processes
2. Obtain knowledge of physics relating to particles interaction with surroundings
3. Learn distribution of particles and physical systems with quantum and classical nature
4. Obtain knowledge about thermo-dynamical nature of physical systems
5. Understands physical systems behaviour at low temperature

Course specific outcome (2nd semester)

1. Learns statistical distribution of particles and their physical behaviour
2. Gain knowledge of low temperature physics and liquid helium

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SEMESTER – II PAPER – 204 CONDENSED MATTER PHYSICS

UNIT-I

Crystal Structure: Crystalline solids, periodic arrays of atoms – Fundamental types of lattices (Bravais Lattice) –Unit cell- Close-packed structures-Quasi crystals- index systems for crystal planes – Simple crystal structures (NaCl, CaCl and diamond) **(Ref.1&4: Chap-1)**

Non-Crystalline Solids: Diffraction Pattern, Glasses, Amorphous Ferromagnets and Semi Conductors, Fiber Optics **(Ref.1: Chap 19)**

Reciprocal Lattice: Reciprocal Lattice – Derivation of Scattered wave amplitude – Reciprocal Lattice vectors – Diffraction conditions. Fourier analysis of the Basis: Structure factor of the bcc and fcc lattices

Liquid crystals- kinds of liquid crystals – types of their crystalline order**(Ref.1: Chap-2)**

UNIT-II

Ionic Crystals: Electrostatic or Madelung energy – Evaluation of the Madelung constant – Ionic crystal radii **(Ref.1: Chap-3)**

Crystal Diffraction: Introduction – Bragg's law – Diffraction by X-rays, electrons and neutrons – Experimental methods for Crystal structure determination – The Laue, powder and rotating crystal methods **(Ref.2: Chap-2)**

Defects in Crystals: Point defects: - impurities – Vacancies – Schottky and Frenkel vacancies – Extrinsic vacancies – Diffusion-Colour centres – F-centres, other centres in Alkali halides

Line defects: -Edge dislocation – Screw dislocations – Burgers vectors – Slip – Plastic deformation –Grain boundaries – Low angle Grain boundaries **(Ref.2 & 4: Chap-12)**

UNIT-III

Band theory of Solids: Energy spectra in atoms, molecules and solids – Bloch theorem – acceleration of the moving electron in the periodic lattice and effective mass of the electron – The tight binding approximation – Construction of Fermi surfaces – Experimental methods in Fermi surface studies: Cyclotron resonance, De Hass Von Alphen effect, Magneto-resistance and the anomalous skin effect **(Ref.3: Chap-9)** Free electron theory**:** Fermi level- Electronic specific heat- Electrical and thermal conductivity- Temperature dependence of electrical resistivity- Hall effect and thermoelectric power. **(Ref.4: Chap-7)**

UNIT-IV

Semiconductors: Classifying Materials as Semiconductors, Chemical Bond in Semiconductors, Band Gap, Intrinsic and Extrinsic Semiconductors, Mobility Drift Velocity and Conductivity of Intrinsic Semiconductors, Carrier Concentration in Intrinsic Semiconductors, Impurity Semiconductors, Impurity States and Band Model, Energy Band Diagram and the Fermi level **(Ref.3 Chapter 10)**

Magnetism: Introduction – review of basic concepts – Wiess theory of ferromagnetism – Heisenberg model and molecular field theory. Spin waves and magnons – Curie Weiss law for susceptibility. Ferri and antiferro-magnetic order. Domains and Bloch – wall energy.

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Ref.1: Chap-16, Ref.2: Chap-17 & Ref.3: Chap-12)

UNIT-V

Superconductivity: Occurrence of superconductivity – Effect of magnetic fields – Flux exclusion and Meissner effect – Heat capacity – Energy gap – Microwave and infrared properties – Isotope effect – Type-1and type-II super conductors. The London equations – Meissner effect and flux penetration – High frequency effects – The BCS theory – BCS ground state- Josephson junctions. **(Ref.1: Chap-12)**

Nano Structures: Electronic Structures of 1D System, Electrical Transport in 1D System, Electronic Structures of 0Dsystem, Electrical Transport in 0Dsystem.**(Ref.1: Chap-22)**

Text and Reference Books:

1. Introduction to solid state physics by Kittel (8^{th} Edition)
2. Solid state physics by R.L. Singhal
3. Solid state physics by S.L. Gupta and V. Kumar
4. Solid state physics by H C Gupta

Course outcome (2^{nd} semester)

1. Obtain knowledge pertaining to structure of different types of solids
2. Learn about experimental methods for solids structure determination and understand about defects of solids
3 Attain knowledge regarding theoretical physics relating to electron movement in solids
4. Attain conduction concepts of solids and their magnetic properties
5. Study about solids super conducting nature and nano science

Course specific outcome (2^{nd} semester)

1. Acquire knowledge of structural and physical properties of solids
2. Study physical properties of solids

Mapping of course comes with program outcomes (Semester-II)

Course outcomes	CO-1	CO-2	CO-3	CO-4
Program out comes (POs & PSOs)	PO1- PO5 PSO1	PO1- PSO1	PO1- PSO1	PO1- PO3 PSO1

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SEMESTER – III PAPER – 301 QUANTUM MECHANICS – II

Unit:I

Time dependent perturbation theory – transition to continuum – Fermi's golden rule – constant perturbation, harmonic perturbation – adiabatic and sudden approximations

Text Book: Chapter 9(Relevant Portion) Introduction to Quantum Mechanics by B.H. Bransden& C.J. Joachain.

Semi classical theory of radiation: Radiative transitions in atoms placed in an electromagnetic field – transition probabilities for absorption and emission – dipole transition – selection rules for allowed transition – forbidden transitions – statistical approach for absorption, spontaneous and induced emission – Einstein A&B coefficients.

References: 1) 11.1 to 11.3 (Partly), 11.4 Introduction to Quantum Mechanics by B.H. Bransden& C.J. Joachain. 2) 9.13 to 9.15 – A text book of Quantum Mechanics – P.M. Mathews & K. Venkatesan.

Unit:II

Matrix formulation of quantum mechanics: Linear Vector Spaces – Hilbert Space, linear operators, linear transformation, matrix representation of an operator and wave function - orthonormality of wave functions. Dirac's Bra and Ket formalism. Schrodinger's equation and the eigen value problem – energy representation. One dimensional harmonic oscillator – solution by matrix mechanics

Quantum dynamics: Schrodinger, Heisenberg and interaction pictures- equation of motion in these pictures.

Text Books: 1) 6.23, 6.24 (relevant portion) - Quantum Mechanics – L.I. Schiff 3rd Edition.

2) 11.4 to 11.7-2 and 11.10 to 11.12 and 8.9 – Quantum Mechanics – Gupta, Kumar & Sharma.

Unit:III

Symmetries and conservation laws: Change of basis – Unitary transformation – induced by translation and rotation – conservation laws, space inversion- Intrinsic parity and parity non conservation– time reversal.

References:1. Scope: 5.5, 5.6 & 5.9 – Introduction to Quantum Mechanics by B.H. Bransden& C.J. Joachain.

2. Scope: 7.7 to 7.9, 7.11 to 7.14 – A text book of Quantum Mechanics – P.M. Mathews and K. Venkatesan.

Identical Particles: Indistinguishability of identical particles, exchange symmetry of wave functions, symmetric and anti-symmetric wave functions – construction. Pauli exclusion principle – connection between spin and statistics – collision of identical particles.

References:1) 10.40 and 10.41 (relevant portion) – Quantum Mechanics 3rd Ed – L.I. Schiff.

2) 10.1 to 10.5 Gupta Kumar and Sharma.

Unit:IV

Scattering Theory: Differential and total scattering cross sections - laboratory and center of Mass Reference frames, Scattering amplitude, scattering by spherically symmetric potentials – partial wave analysis – Phase shifts, scattering by a square well potential – scattering by a perfectly rigid sphere, optical theorem – Ramsauer and Townsend effect – Complex potential and absorption –

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Born approximation for scattering amplitude – condition for validity – scattering by screened coulomb potential by Born approximation.

References:1) 13.1 to 13.4 & 13.6 - Introduction to Quantum Mechanics by B.H. Bransden& C.J. Joachain.

2) 6.1 to 6.8 and 6.11, 6.11 – 1, 6.12 – 2 Quantum Mechanics by Gupta Kumar and Sharma.

Unit:V

Relativistic Quantum Mechanics: Klein-Gordon equation – its success and limitations – Dirac equation for a free particle - α and β matrices central forces and hydrogen atom, relativistic treatment of electron in an electro – magnetic field, spin and magnetic moment of an electron - negative energy states – Theory of Positron.

Text Books: 1) Quantum Mechanics – L.I. Schiff.

2) A Text Book of Quantum Mechanics – Mathew and Venkatesan

Course Outcomes

1. To impart knowledge about the approximation methods (perturbation theory) that deals with complicated problems which are cumbersome to solve with Schrodinger wave equations. To study the structure of molecules and atomic systems and to know how electromagnetic radiation interacts with these systems.

2. To learn the matrix formulation of quantum mechanics and the Dirac bra-ket formalism will be introduced and used throughout to present the principles of Quantum Mechanics in a general context

3. The role of symmetries as the underlying principle of Quantum Mechanics will be emphasized and the use of symmetry principles and operators methods will be discussed.
4. To enable the students to extract the structure of matter from the scattering of particles using different potentials and approximation theories. The use of symmetry principles and operators methods will be discussed.

5. Application of relativistic quantum mechanics and its limitations on particles moving in one dimensional and three-dimensional potentials.

Course specific outcomes

1. Understand angular momentum operators associated with spherical and symmetrical systems - needed to study nuclear structure at high angular momenta.
2. Learn theoretical concepts of quantum mechanical related physical properties

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3. SEMESTER –III PAPER –302 NUCLEAR AND PARTICLE PHYSICS

Unit-1

General Properties of nuclei: Atomic number(Z), mass number(A), Size of the nucleus and radius, nuclear mass - amu, density of nuclear matter -a simple estimate, binding energy cruve, angular momentum, parity and statistics, magnetic dipole moments - Schmidt limits, electric quadrupole moment.

Reference: 1. Introductory Nuclear Physics, by Kenneth S Krane. Chapter 3
2. The Atomic Nucleus by R.D. Evans. Chapter 4

Decay Properties of nuclei : Radioactive decay law, Theory of Radioactive decay, Half-life, Decay rate, Natural radioactive decays, general modes of decay, exotic decay modes and units of decay rates.

Reference: 1. Introductory Nuclear Physics, by Kenneth S Krane. Chapter 6

Unit-2

Alpha Decay: Kinematics of alpha-decay, alpha decay theory, angular momentum and parity of alpha-transitions, alpha spectroscopy.

Reference: 1. Introductory Nuclear Physics, by Kenneth S Krane. Chapter 8

Beta Decay: Energy release in beta decay, Fermi theory of beta decay, angular momentum and parity selection rules, non-conservation of parity, beta spectroscopy.

Reference: 1.Introductory Nuclear Physics, by Kenneth S Krane. Chapter 9
2. The Atomic Nucleus by R.D. Evans. Chapter 17

Unit-3

Gamma Decay: Energetics of gamma decay, Theory of gamma radiation, angular momentum and parity selection rules, internal conversion and internal pair-production, gamma spectroscopy.

Reference: 1. Introductory Nuclear Physics, by Kenneth S Krane. Chapter 10

Fission: Spontanious fission, induced fission, Fission Energy, Theory of fission, angular distribution, kinetic energy distribution, mass distribution.

Reference: 1. Introductory Nuclear Physics, by Kenneth S Krane. Chapter 13
2. Nuclear and Particle Physics, By W.E. Burcham

Unit-4

Nuclear Forces: General Characteristics of Nuclear forces.

Deuteron Problem:The nuclear 2-body bound-system, theory, range and depth of the potential. Excited states of deuteron.

Reference: 1. Introductory Nuclear Physics, by Kenneth S Krane. Chapter 4
2. The Atomic Nucleus by R.D. Evans. Chapter 10

Proton-proton scattering: p-p scattering at low energies, equivalence of p-p and n-p singlet forces, equivalence of n-n and p-p forces, exchange forces, evidence for the existence of non-central forces.

Reference: 1. Introductory Nuclear Physics, by Kenneth S Krane. Chapter 4
2. The Atomic Nucleus by R.D. Evans. Chapter 10

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Unit-5

<u>Neutron-proton scattering</u>: n-p scattering at low energies, phase shift analysis, scattering length, spin dependence of the nuclear forces, shape independent approximation - effective range theory, coherent scattering of slow neutrons.

Reference: 1. Introductory Nuclear Physics, by Kenneth S Krane. Chapter 4

2. The Atomic Nucleus by R.D. Evans. Chapter 10

<u>Particle Physics</u>: Classification of Particles, interactions, symmetries and conservation laws, the quark model, coloured quarks and gluons.

Reference: 1. Introductory Nuclear Physics, by Kenneth S Krane. Chapter 18

<u>Course Outcomes (Cos): -302</u>

1. Student will ***understand*** the fundamental properties, interactions of nuclei and mechanism of radioactive decays and use the ***knowledge*** to comment on the stability or instability of a given nucleus.
2. Students will be able to ***understand*** the theoretical models of nuclear decay and utilise them to predict the stability/instability and comprehend the decay processes.
3. Student will be able to ***apply*** his learned subject knowledge to quantify the energies released in, for example fusion and fission, processes.
4. Student can get the ***familiarity*** on how nuclei are bound together and will be able to ***comprehend*** the interactions between the protons and neutrons inside the nuclei.
5. Student will ***learn*** preliminary interactions, symmetries and conservation laws followed by particle and the Knowledge and the understanding ***acquired***from this course will provide basic underlying fundamentals of nuclear physics and particle physics.

<u>Course Specific Outcomes: 302</u>

1. Students will be able to ***understant*** the theoretical models of nuclear decays and utilise them to predict the stability/instability and comprehend the decay processes.

2 Student will be able to ***apply*** his learned subject knowledge to quantify the energies released in, for example fusion and fission, processes.

3 Knowledge and the understanding **aqcuired** from this course will provide basic fundamentals of nuclear physics and particle physics.

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SEMESTER –III PAPER –303

NUCLEAR RADIATION DETECTORS, DATA AQCUISITION AND ANALYSIS

Unit-1

Introduction: Interaction of electrons, heavy charged particles, neutrons and gamma-rays with matter. Gamma ray interactions: photoelectric, Compton and pair production.

Gas counters: Design and working principle of (1)Ionisation chamber, (2)Proportional counters, and (3) G.M. counters. E - ΔE detectors for charged particle identification and time-of-flight measurement. Neutron detectors

Unit-2

Scintillation detectors: Organic and inorganic Scintillators – theory, characteristics. Sodium iodide NaI(Tl). Lanthanum halides $LaBr_3$(Ce), $LaCl_3$(Ce) and Barium Floride BaF_3.

Solid State Detectors: Si(Li) detectors for X-rays and electrons, HPGe detectors for photon detection- Energy resolution; efficiency and timing considerations- Design and working of Clove detector and Cluster detector, Silicon Surface Barrier detectors.

Unit-3

Pulse Processing and shaping: - Preamplifiers - Voltage, Current and Charge sensitive types. Resistive and Optical feedback- Main amplifiers- pulse shaping, pole-zero compensation, base line restoration and pile up rejection.

Pulse height analysis

Single Channel analyser – integral and differential modes of operation- Simplespectrometer assembly.

Multi-channel analyser: A/D converters (Wilkinson and Flash types)-Multi-channel analyser in PHA and MCS modes.

Unit-4:

Coincidence measurements: Slow - fast coincidence arrangement for measurement of coincidence between radiations. Prompt and chance coincidences - Experimental arrangement for energy and time coincidence measurements.

Unit-5:

Counting Statistics: Statistical errors and their propagation in experimental measurements, χ^2 - test.

References:

2. Nuclear Radiation Detectors S. S. Kapoor & V. S. Ramamurthy.
3. Radiation Detection and Measurement(4th Ed) G. F. Knoll.
4. Techniques for Nuclear and Particle Physics experiments William R. Leo.

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Course Outcomes: Cos-303

1. Student will be able to ***learn*** the mechanisms of interaction of various nuclear radiations with materials and will be able ***understand*** how these interactions are useful in detection processes.
2 Student will be able to ***comprehend*** the knowledge obtained and use skills in selection of a suitable detector for a given purpose.
3 Student will be able to ***establish*** an appropriate combination of electronic circuits required for an experimental radiation detection system and will be able to ***understand*** the timing coincidence methods and will be able ***apply*** it to measure timing correlations between the measured radiations.
4 . Student will ***learn*** about the statistical distributions associated with large volumes of data and will be able to ***apply*** the statistics to ***estimate*** the uncertainties associated with the measurement of radiation.
5. The Knowledge and the understanding ***acquired*** from this course will be useful for future research activities in experimental nuclear physics, if opted for.

Course Specific Outcomes:303

1. The Knowledge and the understanding ***aqcuired*** from this course will be usefull for future research activitites in experimental nuclear physics, if opted for.
2. Student will be able to ***understand*** the timing coincidence methods and will be able ***apply*** it to measure timing correlations between the measured radiations.
3. Student will be able to ***establish*** an appropriate combination of electronic circuits required for an experimental radiation detection system.

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SEMESTER – III PAPER – 304 COMPUTATIONAL METHODS AND PROGRAMMING

UNIT-I

INTRODUCTION TO "C": Characters, constants, variables, keywords and instructions in 'C'. Arithmetic instructions, Assignment statements, Input / Output functions, conditional statements, writing simple programs in 'C'

EXPRESSIONS IN "C": Logical expressions and control statements, decision control, loop control and case control structures

UNIT-II

Functions, arrays, syntax rules, global and state variables. Data types and stacks; structures, pointers, lists and trees. Writing programs in 'C' language connecting with some mathematical back ground

UNIT-III

ROOTS OF EQUATIONS: Iteration method, Bisection method, Newton-Raphson method

SOLUTION TO SIMULTANIOUS LINEAR ALGEBRIAC EQUATIONS: Matrix inversion method, Gauss elimination method, Iterative method, Jacobi's method, Gauss – Seidel method.

UNIT-IV

INTERPOLATION AND EXTRAPOLATION: Finite differences, Newton's forward difference interpolation formula, Newton's backward difference interpolation formula, Newton's divided difference formula, LaGrange's interpolation formula, Richardson's extrapolation

CURVE FITTING AND APPROXIMATION: Least square curve fitting procedures, fitting a straight line, nonlinear curve fitting, data fitting by Cubic Splines.

UNIT-V

NUMERICAL INTEGRATION:Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8th rule, Gauss quadrature.

'C' Programming applied to numerical solutions for problems of UNITS III, IV and V

Text and Reference Books:

1)Computer Oriented Numerical methods by V. Rajaraman2)Computer programming in "C" by V. Rajaraman.

3) Numerical Methods in "C" by Xavier.

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<u>Course outcome (3rdsemester)</u>

1. Learn 'C' language program writing knowledge facilitate to develop logical thinking
2. Develop to make the subject/matter into compact form of writing programs with arrays, functions and structures
3. Learns to solve the problems
4. Learn to write 'C' programs for numerical methods

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5. Designing the problem-solving procedure to utilize variety of times to obtain solutions

<u>Course specific outcome (3rd semester)</u>

1. Obtain computer program writing skills in 'C' language
2. Study application of the program writing skills to the computational methods

Mapping of course comes with program outcomes (Semester-III)

Course outcomes	CO-1	CO-2	CO-3	CO-4
Program out comes	PO1 PSO1	PO1 PO7 PSO1 PSO2	PO1 PO6 PO10 PSO1 PSO2	PO1 PO4 PSO1

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SEMESTER – IV PAPER – 401
NUCLEAR REACTIONS AND PARTICLE ACCELERATORS

Unit-1:
Liquid Drop Model: Analogy between the atomic nucleus and a drop of liquid, Weizsaekar's semi empirical mass formula, Stability considerations of nuclei – Mass parabola – discovery of nuclear fission, energy release in symmetric fission – conditions for spontaneous fission – neutron induced fission of both slow and fast neutrons.
Reference: 1.'Atomic Nucleus' by R.D. Evans

Unit-2:
Nuclear Reactions: Nuclear reaction kinematics, reaction Cross sections, the two step view or the compound nucleus picture due to Bohr, Briet-Wigner single level formulation, Statistical model, Direct reactions, Angular distribution, Spin-parity assignments, Optical model.
Reference:
2. 'Nuclear and Particle Physics' by E.B. Paul.

Unit-3:
Heavy Ion Reactions at low energies: Coulomb barrier, Interaction potentials, elastic scattering, transfer reaction, fusion reaction: Formation and decay of compound nucleus, particle evaporation and fission of Compound nucleus, Fission barrier

Unit-4:
Nuclear Astrophysics – Nucleosynthesis: Big bang – the beginning, Primordial nucleosynthesis, light element (A<60)synthesis (hidrogen burning, CNO Cycle, carbon burning), heavy (A>60) element synthesis, Nuclear Cosmochronology.
Reference: Introductory Nuclear Physics, by Kenneth S Krane. Chapters 14 and 19

Unit-5:
Cyclotron: Frequency Modulated Cyclotron, Variable energy cyclotron.
Linear Accelerator(LINAC): heavy ion LINAC, proton LINAC
DC Devices: Cockcroft Walton Accelerator, Van de Graff Accelerator, Tandem Accelerator, Pelletron.
Beam transport systems: bending and focussing devices.

Reference:
1 Nuclear Physics by E.G. Green.
2 Nuclei and Particles by E. Serge.
3 Particle Accelerators by M.S. Livingston and John P. Blewett.
4 Principles of Cyclic particle Accelerators by J.J. Livingood.

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Course Outcomes: Cos-401

1. Student will learn to ***compare*** the nuclei to other physical systems to ***comprehend*** the behaviour of nucleus as a whole.

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2. Student will ***understand*** the mechanisms involved in various types of nuclear reactions and will be able ***distinguish*** one reaction type from the other and will be able ***compute*** the reaction energies, cross sections and kinematics to ***establish*** types of reaction.
3. Student will learn how the universe is created from Big-bang and will understand how nuclear reactions play important role in early universe in creation of chemical elements in nuclear reactions.
4. Student will understand how various types of accelerators work and they will be able to estimate energies of accelerated particles.
5. Knowledge and the understanding acquired from this course will be useful for future research activities, if opted for.

<u>Course Specific Outcomes: 401</u>

1. Student will be able to construction possible connectivity between creation of chemical elements in nuclear reactions.
2. Student will understand how various types of accelerators work and they will be able to estimate energies of accelerated particles.
3. Knowledge and the understanding aqcuired from this course will be usefull for future research activitites, if opted for.
4. Student will learn how universe is created from Big-bang.

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SEMESTER – IV PAPER – 402 REACTOR PHYSICS

UNIT-I

Production of Neutrons: Classification of Neutrons – Slow, Intermediate and Fast Neutrons – detection of neutrons – interaction of neutrons with matter in bulk: Slowing down – thermal neutrons –diffusion of thermal neutrons

Principles of neutron detection – detection of slow neutrons with foil activation method – thermal neutrons obeying the 1/v law – Scintillators as slow neutron detectors – fission chambers for detection thermal neutrons – proportional counters for detection of fast neutrons by recoil protons – scintillation detectors for fast neutrons

UNIT-II

Moderation of neutrons: The elastic collision – Average logarithmic energy decrement – Slowing down density – Diffusion of neutrons – The basic diffusion equation – Diffusion of thermal neutrons from an infinite plane source – Point source considerations – Diffusion length

Neutrons reactions: absorption – Radiative capture reactions – emission alpha particles – reactions with fast neutrons – inelastic scattering – elastic scattering – The Maxwell- Boltzmann distribution - Departure from Maxwellian distribution – structural changes caused by neutron interactions

UNIT-III

Nuclear Fission: Discovery of nuclear fission; fission types-fission products- fission fragments-fission cross sections and thresholds - mass and energy distributions of the fission products-neutrons emission in fission – energy distributions of the neutrons emitted in fission –energy release in fission – fissile and fertile materials – spontaneous fission - theory of fission process-Fission chain reaction – Neutron Balance in chain reaction – Four-factor formula

UNIT-IV

Reactors Classification – general features- history of reactor development –efficiency.

Thermal reactors – neutron cycle - Multiplication factor for thermal reactors - Bare homogeneous thermal reactor –Geometrical and Material Buckling – Neutron balance in a thermal reactor – Calculation of critical size

Heterogeneous thermal reactors – Properties of Heterogeneous systems –Critical size of a thermal reactor – power and breeding- controlled thermonuclear reactions – Resonance capture – Resonance escape probability – Advantages and Disadvantages of Heterogeneous systems.

UNIT-V

The Behaviour of a thermal reactor with prompt and delayed neutrons – The in-hour formula – Temperature effects – Fission product poisoning – Use of Coolants and Control rods

Nuclear fuel cycles: uranium – plutonium cycle-Thorium-uranium cycle-. Other fuel cycles-uranium enrichment

Breeding: general considerations- breeding ratio-breeding gain-doubling time-Breeder reactors: -fast breeders-thermal breeders- advanced breeding concepts

Text and Reference Book:

1. Nuclear physics by Irving Kaplan

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2. Introduction to Neutron Physics" by L.F. Curtis.
3. Physics of nuclear reactors by Suresh Garg, Feroz Ahmed, L.S.Kothari
4. Nuclear reactor engineering by Samuel Glasstoneand AlexanderSesonske

<u>Course outcome (4th semester)</u>

1. Learns basic knowledge of neutrons and their detection
2. Understand interaction of neutrons with matter and their movement profile
3. Obtain knowledge about fission and neutrons role in fission process
4. Deep understanding about reactors and their uses
5. Analysis of reactor materials and their role

<u>Course specific outcome (4th semester)</u>

1. Gain the knowledge of neutron physics
2. Study reactor physics

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SEMESTER – IV PAPER – 403 NUCLEARSPECTROSCOPY

Unit-1:

Shell Model: Evidence for shell structure in nuclei, Central potential forms, spin orbit interaction, magic numbers from the spin-orbit splitting of energy levels.

Extreme Single Particle Shell Model: Pairing assumption, spins, parities and magnetic dipole moments of the ground and low-lying excited states of nuclei. Nuclear isomerism in shell model.

Unit-2:

Collective Model: Elementary considerations, evidence for the collective motions within the nuclei, pure vibrational states, deformed nuclei, pure rotational states.

Nilsson's Model: Independent motions of nucleons in a non-spherical potential – single particle states of deformed nuclei.

beta and gamma vibrational bands – particle-rotational coupling.

High spin states, rotational alignment, back bending effect.

Reference:

1. Nuclear and Particle Physics by E.B. Paul.
2. Nuclear Physics Theory and Experiment by R.R. Roy and B.P. Nigam.

Unit-3:

Characteristics of nuclear energy levels and nature of the connecting transitions – radioactive decay and heavy ion induced nuclear reactions.

Energies and intensities of gamma rays and conversion electrons – construction of the level scheme using coincident methods.

Gamma transition probabilities, Weisskopf's single particle estimates.

Unit-4:

Life times of nuclear excited states – delayed coincidence with gamma rays and pulsed beam – Doppler shift attenuation, recoil distance and Coulomb excitation methods.

Internal conversion coefficients(ICC): Experimental ICC, sub-shell ratios.

Unit-5:

Spins and parities of nuclear excited states and the nature of the connecting transitions:

(a) Gamma ray directional correlations, spin and parities, mixing ratios.

(b) Directional Correlation of gamma rays in Oriented nuclear excited levels produced in heavy ion reactions, multi-polarities of gamma transitions from DCO ratios.

(c) Gamma ray Linear polarization measurement: Compton polarimeter, determination of partity change in gamma decay transitions.

References:

1. Radiation Detection and Measurement by G. F. Knoll
2. Techniques for Nuclear and Particle Physics Experiments by William R Leo.
3. Introduction to Experimental Nuclear Physics by R. M. Singru.
4. Introductory Nuclear Physics by K. S. Krane.

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Course Outcomes: Cos-403

1. Student will ***learn*** how nucleons are arranged inside the nucleus by ***comparing*** the models of atom and nucleus.
2. Student will be able to ***predict*** the properties of nuclei using nuclear models***knowledge*** and will be able to ***distinguish*** spherical and deformed shapes of nuclei by ***observation*** of the energies and other properties of excited states.
3. Student will be able to ***compute*** the energies of excited states from different models and will ***understand*** about various experimental methods of nuclear spectroscopy.
4. Student will be able to ***identify*** the appropriate method for any given measurement and will also be able to **assign** spin-parity of excited states from experimentally determined parameters.
5. Knowledge and the understanding acquired from this course will be useful for future research activities, if opted for.

Course Specific Outcomes: 403

1. Student will be able to ***distinguish*** spherical and deformed shapes of nuclei by ***observation*** of the energies and other properties of excited states.
2 Student will be able to ***compute*** the energies of excited states from different models.
3. Student will be able to **assign** spin-parity of nuclear excited states from experimentally determined parameters.

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SEMESTER – IV PAPER – 404

NUCLEAR TECHNIQUES IN MATERIAL SCIENCE AND RADIATION PHYSICS

Unit 1

Trace elemental analysis – X-ray fluorescence technique (XRF) – Particle induced x-ray emission technique (PIXE), Particle induced gamma ray emission technique (PIGE) – Neutron activation analysis technique (NAA) – experimental arrangement – applications in environmental pollution studies, medicine, geology.

Rutherford back scattering spectroscopy – basic principle – experimental arrangement – applications in surface physics. Auger electron spectroscopy – basic principle – experimental arrangement – applications in surface physics

Ion beam channeling – basic principle – experimental arrangement – applications

Unit 2

Nuclear Magnetic Resonance – Nature of the phenomenon – Analysis – Experimental method – Determination of nuclear magnetic moments – structural studies.

Positron annihilation technique – basic principle – experimental arrangement for positron life time measurement – Doppler broadening and angular correlation studies – applications

Neutron logging - Bulk density – applications in Geophysics.

Mossbauer Spectrometry – Principle and Applications

Accelerator Mass Spectrometry (AMS): Principle and applications

Text and Reference Books:

1. Back Scattering Spectrometry by J.W. Mayer and M.A. Nicolet. Academic Press, New York,1978.
2. Positrons in Solids, Edited by P. Hautojarvi, Springer – Verlag, New York, 1979.
3. Elemental X- ray analysis of materials by J.C. Russ etal, Edax Laboratories
4. Analytical Techniques for Material Characterisation by W.E. Collins (Editor)
5. Solid State Physics by (R.L. Singhal)
6. Accelerator Mass Spectrometry: ultrasensitive analysis for global science by Claudio Tuniz (etal)

Unit 3

Units of radio activity and radiation exposure – Curie, Roentgen, Becquerel – RAD – REP- REM – Gray – Sievert - RBE, AD and DE and their relations.

Protection of personnel against nuclear radiations – Radiation monitoring – film badge technique - Radioactive waste management – planning and use of radio isotopes and chemical laboratories

Unit 4

Structure of the living cell – cell division – direct and indirect action of ionizing radiation – Biological effects of radiations – somatic and genetic effects

Applications of radio isotopes in medicine – use of I^{131} for the study of the thyroid – use of radioisotopes in the diagnosis and treatment of cancer – radiation therapy

Unit 5

Applications of radio isotopes in industry – principle of industrial radiology – non destructive testing of materials

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Applications of radio isotopes in agriculture – detection of plant diseases by tracer methods – study of photo synthesis – uptake of nutrients – radiation induced genetic changes and crop improvement – preservation and sterilization of foods and drugs

Text and Reference Books:

1. Source Book on Atomic Energy by Samuel Glasstone.
2. Fundamentals of Radiochemistry (IANCAS) by D.D.Sood, A.V.R.Reddy,N.Ramamoorthy

Course Outcomes:

1. Understanding the basic knowledge of instruments and applications of Nuclear Techniques using for structural, environmental pollution studies, medicine, geology, etc. of the materials.
2. The content of this paper is very important to develop the research in material science, geophysics, atmospheric and ocean sciences.
3. Basic knowledge on Radio activity, radiation exposure, protection against nuclear radiation and waste management
4. Applications of radioactive isotopes in health and biological effects of radiation
5. Applications of radioactive isotopes in industry, agriculture and preservation and sterilization of foods and drugs

Course specific Outcomes

1. Study about basic principles and working functions of various nuclear analytical techniques
2. Obtain knowledge of characterisation of materials with different nuclear analytical techniques

Mapping of course comes with program outcomes (Semester-IV)

Course outcomes	CO-1	CO-2	CO-3	CO-4
Program out comes (PO)	PO1 PO7 PSO1 PSO2 PSO3	PO1 PO9 PSO1 PSO4	PO1 PO7 PO10 PSO1 PSO2	PO1 PO8 PO10 PSO1 PSO3

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