ANDHRA UNIVERSITY
DEPARTMENT OF NUCLEAR PHYSICS
CURRICULAM FOR M.Sc. (NUCLEAR PHYSICS) PROGRAMME
EFFECTIVE FROM 2012 – 13 ADMITTED BATCH

Semester I	**Name of the Paper**	**Max. Marks**	**Grade Point**
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
Paper-207(Non – Core#)	Introductory Nuclear Physics and Nuclear Power	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(Non – Core#)	Experimental Techniques in Applied Nuclear Physics	100	4
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*	Nuclear Physics Practical-II	100	4
Paper 406*	Computer Programming Lab-II	100	4
Paper 407*	Project	200	8
Paper 408	Comprehensive Viva – Voce	100	4

*** In Semester-IV, choice between Paper 407 (Project) or Papers 405&406 Practicals**

 # Non-core papers offered in this Department for other department students:
Semester-II: Introductory Nuclear and Neutron Physics
Semester-III: Experimental Techniques and Applied Nuclear Physics

SEMESTER – I PAPER – 101

MATHEMATICAL METHODS OF PHYSICS

MODULE - I

1. **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.

   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

   Text Book Reference Book:
   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

2. **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

   Text and Reference Book: Mathematical Methods for Phyisicists by G. Arfken
   Ch 15 Sec 1,7,8, 9,11,

MODULE - II

3. **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.

   Text and Reference Book : 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

4. **Tensor Analysis**:

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

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

SEMESTER – I PAPER-102

CLASSICAL MECHANICS

MODULE-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.

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.

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.

Text Book: Classical Mechanics (3rd Edition) Chapters 1,2,3,4,5
By Herbert Goldstein, Charles P. Poole and John L. Safko

MODULE - II

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.

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.

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.

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.

Text Book: 1. Classical Mechanics (3rd Edition) Chapters 7,8,9,10
By Herbert Goldstein, Charles P. Poole and John L. Safko

SEMESTER – I PAPER – 103

ELECTRODYNAMICS

MODULE - I

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)

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)

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.)

MODULE-II

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)

Electrodynamics of charged particle in Electromagnetic fields: Lagrangian and Hamiltonian for a Relativistic charged particle in external electromagnetic fields. Lagrangian for the electromagnetic fields.
(Scope: JDJ, Ch.12, Sec.1, 7.)

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. L.B. Laud: 'Electromagnetics'. Wiley Eastern Ltd.

SEMESTER – I PAPER –104

ELECTRONIC DEVICES AND CIRCUITS

MODULE I

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.
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.

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.

MODULE II

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.

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

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.

SEMESTER – II PAPER – 201

ATOMIC AND MOLECULAR PHYSICS

MODULE - I

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, singlet and triplet series in two valance electron systems. Spectrum of helium atom.

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.

Effect of electric and magnetic fields on the spectrum of an atom—Zeeman effect—classical interpretation of Normal Zeeman effect, Vector atom model and 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 of one electron atom.

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.

MODULE - II

Molecular spectra of diatomic molecules-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, Vibrational spectra-- diatomic molecule as a harmonic oscillator, fine structure of rotation-vibration bands, Electronic transitions and Frank-Condon principle.

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.

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.

SEMESTER – II PAPER – 202

QUANTUM MECHANICS - I

MODULE – 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)

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)

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)

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)

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

MODULE – II

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)

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))

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

Text and Reference Books:
(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
(5) A Text Book of Quantum Mechanics – P.M. Mathews and K. Venkatesan**.**

SEMESTER – II PAPER – 203

STATISTICAL MECHANICS

MODULE – I

General principles and Foundations of statistical mechanics:
Introduction – 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

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

MODULE – II

Quantum Statistics:
Introduction – The density matrix – Bose Einstein statistics – Fermi–Dirac statistics – Maxwell-Boltzmann statistics – Results and comparison of three statistics - Bose Einstein gas – 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 – Nuclear spin statistics – ortho and para hydrozen.

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

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.

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

Text and Reference Books:

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

SEMESTER – II PAPER – 204

CONDENSED MATTER PHYSICS

MODULE – I

Crystal Structure: Crystalline solids, periodic arrays of atoms – Fundamental types of lattices – index systems for crystal planes – Simple crystal structures (NaCl, CaCl and diamond) (Ref.1 : Chap-1)

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

Reciprocal Lattice: Reciprocal Lattice – Derivation of Scattered wave amplitude - Reciprocal Lattice vectors – Diffraction conditions (Ref.1 : Chap-2)

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)

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

Defects in Crystals: *Point defects:-* impurities – Vacancies – Schottky and Frenkel vacancies – Extrinsic vacancies – Diffusion-Color centers – F-centers , other centers in Alkali halides
Line defects: -Edge dislocation – Screw dislocations – Burgers vectors – Slip – Plastic deformation – Crystal growth *Planer defects:-* Stacking faults – Grain boundaries – Low angle Grain boundaries (Ref.2 : Chap-12)
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)

MODULE – II

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 – Heisenerg model and molecular field theory. Spin waves and magnons – Curie Weiss law for susceptibility. Ferri and antiferro-magnetic order. Domains and Bloch – wall energy. (Ref.1 : Chap-16, Ref.2: Chap-17 and Ref.3: Chap-12)
Superconductivity: Occurrence of superconductivity – Effect of magnetic fields – Flux exclusion and Meissner effect – Heat capacity – Energy gap – Microwave and infrared properties – Isotope effect – The London equations – Meissner effect and flux penetration – High frequency effects – The BCS theory – BCS ground state (Ref.1 : Chap-12)

Nano Structures : Imaging techniques for 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 C.Kittel (8^{th} Edition)
2. Solid state physics by R.L.Singhal
3. Solid state physics by S.L.Gupta and V.Kumar

SEMESTER – III PAPER – 301
QUANTUM MECHANICS – II

MODULE – 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 electro magnetic 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.

Text Books: **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.**

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. Schroedinger's equation and the eigen value problem – energy representation. One dimensional harmonic oscillator – solution by matrix mechanics.
Quantum dynamics: Schroedinger, 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.

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.

Text Books: **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.

Books for Reference: 1. Quantum Mechanics – Merz Bacher .
2. Quantum Mechanics Vol-II – A.P.Messaiah

MODULE - II

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

Text Books: **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.

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.

Text Books: **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.

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

SEMESTER –III PAPER –302

NUCLEAR AND PARTICLE PHYSICS

MODULE - I

General Properties of nuclei:
Size of the nuclei, nuclear binding energy, nuclear angular momentum, parity and statistics, nuclear magnetic dipole moments and its experimental measurement, Schmidt limits, nuclear quadrupole moment.

Scope: 1. Introductory Nuclear Physics, by Kenneth S Krane. Sec. 3.1, 3.3 to 3.6
2. The Atomic Nucleus by R.D. Evans. Chapter 4.1 to 4.7

Beta Decay:
Energy release in beta decay, Fermi theory of beta decay, shape of the beta spectra, angular momentum and parity selection rules, comparative half lives, non conservation of parity, beta spectroscopy.

Text and Reference:
1. Introductory Nuclear Physics, by Kenneth S Krane. Sec. 9.1, 2,3,4,5,9 & 10.
2. The Atomic Nucleus by R.D. Evans. Chapter 17

Gamma Decay:
Energetics of gamma decay, angular momentum and parity selection rules, internal conversion, lifetimes for gamma emission, gamma ray spectroscopy.

Text and Reference: 1. Introductory Nuclear Physics, by Kenneth S Krane. Sec. 10.1, 4, 6 , 7 & 8

MODULE-II

Nuclear Forces:
General Characterstics of Nuclear forces, The nuclear 2-body problem--- deuteron and its simple theory—range and depth of the potential, excited states of deuteron.
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.
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.

Text and Reference: 1. The Atomic Nucleus by R.D. Evans. Chapter 10 sec. 3,5,6,7 &8

Particle Physics:
Particle interactions and families, symmetries and conservation laws--- energy and momentum, angular momentum, parity, Baryon number, lepton number, isospin, strangeness and charm, the quark model, colored quarks and gluons, Grand unified theories (preliminaries only)

Text and Reference: 1. Introductory Nuclear Physics, by Kenneth S Krane. Sec. 18.1,2,3,4 &8

SEMESTER – III PAPER – 303

NUCLEAR RADIATION DETECTORS, DATA AQCUISITION AND ANALYSIS

MODULE – I

Introduction: Principle of detection of photons, charged particles and neutrons. (Interaction of light and heavy charged particles with matter, photoelectric, Compton and pair production)

Gas counters: Ionisation chambers, Proportional counters, Neutron detectors and G.M. counters.

Scintillation detectors: Organic and inorganic Scintillators – theory, characteristics and detection efficiency. BGO detectors – advantages of BGO over Scintillation detectors.

Solid State Detectors: Silicon Surface Barrier detectors, E - ΔE detection for charged particles, Si(Li) detectors for X-rays and electrons, HPGe detectors for photon detection. Energy resolution, efficiency and timing considerations. Introduction to Cluster and Clove detectors.

MODULE II

DATA ACQUISITION AND ANALYSIS

Pulse Processing and shaping:- Preamplifiers - Voltage, Current and Charge sensitive types. Resistive and Optical feed back. 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. Simple spectrometer assembly.

Multi channel analyser: A/D converters (Wilkinson and Flash types). D/A converters (R-2R ladder type). Principle of operation and performance indices. Multi channel analyser in PHA and MCS modes.

Coincidence measurements : Slow - fast coincidence arrangement for measurement of coincidence between radiation. Prompt and chance coincidences. Experimental arrangement for energy and time coincidence measurements. Compton suppression spectrometer (Ge(Li) detectors with anti Compton BGO shield).

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

Text and Reference Books:

1. Nuclear Radiation Detectors — S. S. Kapoor and V. S. Ramamurthy.
2. Radiation Detection and Measurement — G. F. Knoll.
3. Techniques for Nuclear and Particle Physics experiments — William R. Leo.

SEMESTER – III PAPER – 304

COMPUTATIONAL METHODS AND PROGRAMMING

MODULE I

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

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

3) INTERPOLATION:
Finite differences, Newton's forward difference interpolation formula, Newton's backward difference interpolation formula, Newton's divided difference formula, LaGrange's interpolation formula

4) CURVE FITTING AND APPROXIMATION:
Least square curve fitting procedures, fitting a straight line, non linear curve fitting, data fitting by Cubic Splines.

5) NUMERICAL INTEGRATION:
Trapezoidal rule, Simpson's 1/3 rule, Simpson's $3/8^{th}$ rule, Gauss quadrature.

MODULE II

PROGRMMING IN "C"

1) 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'.

2) EXPRESSIONS IN "C": Logical expressions and control statements, decision control, loop control and case control structures, functions, arrays, syntax rules, global and state variables. Data types and stacks, structures, pointers, lists and trees.

3) 'C' Programming applied to numerical solutions for problems in Module I

Text and Reference Books:

1) Computer Oriented Numerical methods by V. Rajaraman
2) Computer programming in " C " by V. Rajaraman.
3) Numerical Methods in "C" by Xavier.

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NUCLEAR REACTIONS AND PARTICLE ACCELERATORS

MODULE – I

NUCLEAR REACTIONS

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.

Text Book:
1. 'Atomic Nucleus' by R.D. Evans

Nuclear Reactions: Types of reactions and Conservation laws – Energetics of Nuclear Reactions – Cross sections – Neutron induced reactions – Slow neutron resonance – the two step view or the compound nucleus picture due to Bohr – Entrance and Exit channels – Level width and Level Spacing – Resonance reactions – Briet-Wigner single level formulation – Statistical model, Average level spacing and reduced width – Direct interaction Mechanisms – Angular distribution in stripping, pick up and inelastic scattering reactions – Spin, parity assignments – Total neutron cross sections. Gross structure problem – Optical model and its explanation of gross structure problem.

Text Books:
1. 'Nuclear and Particle Physics' by E.B. Paul.
2. 'Fast Neutron Physics' Part-II edited by J.B. Marion and J.L. Fowler.

MODULE –II

PARTICLE ACCELERATORS

Cyclotron – Phase stability and Orbital Stability, FM Cyclotron (Synchro-Cyclotron), Microtron – Alternate gradient (strong) focusing – Variable energy cyclotron (AVF Cyclotron).

Linear Accelerator – Phase stability – modern linear accelerator for electrons and charged particles.

Cockcroft Walton Accelerator – Production of 14MeV neutrons.
Van de Graaf Accelerator - Tandem Van de Graaf Accelerator – Pelletron.

Betatron – Electron Synchrotron and Proton synchrotron – Strong Focusing – Orbital Stability and Phase Stability – Beam transport.

Text and Reference Books:
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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REACTOR PHYSICS

MODULE-I

Production of Neutrons: Classification of Neutrons – Slow, Intermediate and Fast Neutrons – Radioactive Sources – Photo neutron sources – Particle accelerators as sources of neutrons – Mono energetic neutrons – Reactors as source of thermal neutrons – Distribution of energy of neutrons in a thermal reactor – Thermal column – The cadmium ratio – Measurement of thermal neutron flux using foil activation method.

Interaction of neutrons with matter in bulk – Moderation of neutrons – The elastic collision – Average logarithmic energy decrement – Slowing down density and slowing down flux – Space distribution of slowing down density – Transport mean free path – Fremi Age – Point source consideration – Experimental determination of Fermi Age – Diffusion of neutrons – The basic diffusion equation – Diffusion of thermal neutrons from a infinite plane source – Point source considerations – Diffusion length and its experimental determination.

Text and Reference Books:
1. "Introduction to Neutron Physics" by L.F. Curtis.

MODULE-II

Nuclear Fission – Characteristics of Fission reaction – Fission chain reaction – Neutron Balance in chain reaction.

Reactor types – Multiplication factor for thermal reactors – Four-factor formula – Bare homogeneous thermal reactor – Critical equation – Geometrical and Material Buckling – Neutron balance in a thermal reactor – Calculation of critical size and composition in simple cases.

Heterogeneous reactors – Properties of Heterogeneous systems – Resonance capture – Volume and surface absorption – Resonance escape probability – Advantages and Disadvantages of Heterogeneous systems.

The Behavior of a Bare thermal reactor with prompt and delayed neutrons – The inhour formula – Temperature effects – Fission product poisoning – Use of Coolants and Control rods.

Breeder and Power reactors – Elementary considerations.

Text and Reference Book:
1. "Elements of Nuclear Reactor theory" Edited by Samuel Glasstone.

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NUCLEAR SPECTROSCOPY

MODULE – I

NUCLEAR MODELS

Shell Model**:** Evidence for shell structure in nuclei –square well potential – energy level scheme – spin orbit potential, reproducibility of magic numbers with the spin orbit splitting of energy levels – Extreme Single Particle Model, explanations of spins, parities and magnetic dipole moments of the ground and low lying excited states of nuclei, nuclear isomerism in terms of shell model.

Collective Model**:** Elementary considerations, evidence for the collective motions within the nuclei, pure vibrational states, deformed nuclei, pure rotational states - motions of nucleons in a deformed or non-spherical potential - exited states of deformed nuclei – Nilsson's Model - beta and gamma vibrational bands – particle-rotational coupling.
RAL Model**:** High spin states – back bending – rotational alignment.

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

MODULE - II

EXPERIMENTAL METHODS

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 – energy matrix.
Life times of nuclear excited states – delayed coincidence with gamma rays and pulsed beam – Doppler shift attenuation, recoil distance and Coulomb excitation methods – transition probabilities – single particle estimates.
Spins and parities of nuclear excited states and the nature of the connecting transitions:
(a) Angular distributions in stripping and pickup reactions – angular momentum transfer – spectroscopic factors.
(b) Internal conversion coefficients – XPG, NPG, summing and coincident methods – sub-shell ratios – mixing ratios - dynamic nuclear structure effects – penetration parameters.
(c) Electron-gamma and gamma-gamma directional correlations – spin and parities – particle parameters - mixing ratios.
(d) Directional correlation of gamma rays from nuclear excited levels populated in heavy ion induced nuclear reactions – multi-polarities from DCO ratios – linear polarization.
Static magnetic dipole and electric quadrupole moments of nuclear excited states – magnetic fields and electric field gradients at the nucleus:
(a) Perturbed angular correlations – integral and differential correlations – experimental arrangement.
(b) Mossbauer spectroscopy – principle of the method - experimental arrangement.

Text and Reference Books:
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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NUCLEAR TECHNIQUES IN MATERIAL SCIENCE AND RADIATION PHYSICS

MODULE –I

Trace elemental analysis – X-ray fluorescence technique – particle induced x-ray emission technique – neutron activation analysis technique – 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

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

Ion beam channeling – basic principle – experimental arrangement – applications

Neutron logging - Bulk density – applications in Geophysics.

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. Hauto jarvi, 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)

MODULE –II

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

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

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

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.

SEMESTER – II PAPER – (Non – Core)

Introductory Nuclear Physics and Nuclear Power

MODULE I

RADIOACTIVITY: Natural Radioactivity, Units of radioactivity, Alpha, Beta and gamma radiations.

Interaction of radiation with matter. The law of radioactive decay, Artificial Radio Activity and need for generating artificial radio active Isotopes. Determination of the age of earth, Carbon dating, Archaeological Time scale.

THE NUCLEUS: Constituents of the nucleus and their properties, Size of the nuclei, Nuclear spin, parity and statistics.

THE SHELL MODEL OF A NUCLEUS: The evidence that led to the shell model, main assumptions,

NUCLEAR FORCES: General characteristics of Nuclear forces, the ground state of the deuteron,, magnetic dipole and electric quadrupole moments of the deuteron. Exchange forces-Meson theory of nuclear force.

Text and Reference Books: Introductory Nuclear Physics by K. S. Krane.

MODULE II

Nuclear Fission and Fusion: Discovery of nuclear fission and its properties. Natural and artificially induced fission. Fission chain reaction and its basics. Critical and sub critical and Super critical states of induced fission. Fissionable materials, their natural abundance and production by other methods.

Controlled Nuclear Fission and its peaceful applications. Working principle of Nuclear Reactor and its operation. Fissile and fertile materials. Fast Breeder Reactors

Nuclear Power Generation: Myths and Facts. Status of Nuclear Power generation in India and future scope. World scenario of Nuclear Power generation. Political strategy of India in becoming a self sufficient Nuclear Power generation Nation – Hurdles and Solutions.

Text and Reference Books:

1. Source Book On Atomic Energy by Samuel Glasstone.

SEMESTER – III PAPER – Non Core

Experimental Techniques in Applied Nuclear Physics

Moduel-1

Trace elemental analysis: a) X-ray fluorescence (XRF)technique b) particle Induced X-ray emission technique (PIXE) c) Neutron Activation Analysis – experimental arrangement of the above techniques- applications of the above techniques in environmental science, Physics, Geology, Medicine, and Botany.

Rutherford backscattering (RBS)technique - basic principle and experimental details – applications of this technique in material Science, Solid State Physics and Nuclear Physics.

Nuclear Magnetic Resonance (NMR)- nature of the phenomenon – experimental details – Application of this technique in Nuclear Physics, Solid State Physics and Chemistry.

X-ray diffraction technique – principle and working – Laue powder technique – Application s of this technique in solid state physics to study the crystal structure.

Moduel-2

Protection of personnel against nuclear radiation – radiation monitoring and film badge technique.
Application of radioisotopes in medicine – study of the function of thyroid gland using I-131 isotope –

Use of radioisotopes in medical field to trace out restricted blood flow regions in the body, to trace out of the distribution of Fe and Vitamin B-12 in different body organs.

Radiation therapy: Tele therapy – Use of Cobalt-60 isotope in the treatment of cancerous tumors – dose depth relations – Therapeutic ratio – Fractionation –Oxygen effect – survival of patients. Brauchy therapy – Treatment of leukemia – Use of high energy C –ions in the treatment of cancer.

Application of radioisotopes in industry – wearing capacity of materials – measurement of liquid level s in closed containers – radioactive gauging techniques – Non destructive testing of materials (NDT).

Applications of radioisotopes in agriculture – study of photosynthesis- radiation induced genetic changes in seeds and crop improvement – Use of tracer techniques to know about the uptake of phosphorus – sterilization of food materials.

Biological effects of radiation – Mechanism – Factors affecting biological damage – equivalent dose and dose equivalent – Acute effects of radiation –Effective doses in Nuclear Medicine tests.

Text and Reference Books:

1. Source Book On Atomic Energy by Samuel Glasstone.
2. Nuclear Medicine Physics, The basics by Ramesh Chandra.
3. The Physics Radiology by Harold Elford Johns & J.R. Cunningham.
4. Safe Handling of Radioactive isotopes by E. H. Quinby.
5. Protection against Radiation, A Practical Hand Book by John. D. Abbatt, J. R. A. Lakey and D. J. Mathias.