Syllabus for RET Examination

University of Gour Banga

SUBJECT: PHYSICS

Mathematical methods

1. Functions of a complex variable: Differentiability. Cauchy-Riemann equations. Harmonic functions. Analytic functions. Entire functions. Multiple-valued functions. Branch points and branch cut. Riemann surfaces. Complex integration. Contour integrals. Darboux inequality. Cauchys theorem. Cauchys integral formula. Liouvilles theorem. Moreras theorem. Taylor and Laurent series. Singular points and their classification. Residue theorem. Jordans lemma. Application of residue theorem to the evaluation of definite integrals and the summation of infinite series. Integrals involving branch point singularity. Analytic continuation. Schwarz reflection principle.

2. Fourier integral theorem. Fourier and Laplace transforms. Inverse transforms. Persevall's theorem. Convolution theorem. Solution of ordinary and partial differential equations by transform methods.

3. Differential equations and Greens function:

   Second order Linear differential Equations methods of solution; Sturm-Liouville problem. Legendre, Bessel, Hermite and Laguerre functions and polynomials: Differential Equations, series solutions, recursion relations, orthonormality, position of zeroes, connection with Sturm-Liouville problem. Partial Differential equations methods of solution: separation of variables method, eigenfunction expansion method, integral transform method. Greens function: definition and properties; methods of computation: direct computation, eigenfunction expansion method, integral transform method.

4. Tensor analysis: Coordinate transformations, scalars, definition of tensors, contravariant, covariant and mixed tensors, addition of tensors, inner and outer products, contraction, symmetric and anti-symmetric tensors, quotient law, Kronecker delta and Levi-Civita symbols, Euclidean and Riemannian space, fundamental metric tensor, conjugate tensor, associate, contravariant and covariant vectors.

5. Group theory: Groups. Definition and examples. Order of a group. Multiplication table. Rearrangement theorem. Generators of a finite group. Conjugate elements and classes. Subgroups. Cayleys theorem.

Cosets. Lagranges theorem. Direct product of groups. Invariant subgroups. Factor group. Isomorphism and homomorphism. Permutation groups. Distinct groups of a given order. Cyclic and noncyclic groups.

6. Group representations. Definition of representation. Faithful and unfaithful representations. Equivalent representations. Invariant subspaces and reducible representations. Reducibility of a representation. Irreducible representation. Schurs lemmas.Orthogonality theorem. Construction of some groups (C_{2v}, C_{3v}, D_{2h})

7. Discrete, continuous, and mixed continuous groups. Topological and Lie groups. Axial rotation group SO(2). Rotation group SO(3). Special unitary groups SU(2), SU(3) and their applications in physics.

Classical Mechanics

1. Review of Lagrangian and Hamiltonian formalisms: Legendre transforms. Hamiltons function and Hamiltons equations of motion. Simple applications. Lagrangian and Hamiltonian of relativistic particles. Action. Principle of least action. Hamiltons principle. Maupertuis principle. Euler Lagrange equations of motion from Hamiltons principle. Hamiltons equations of motion from Hamiltons principle. Noethers theorem.

2. Central force: Two body central force problem. classification and stability of orbits. condition for closure. integrable power laws. Keplers problems. orbits of artificial satellites. Virial theorem. Scattering in a central force field. Rutherford scattering. three body problem.

3. Rigid body motion:Kinematics of rigid body motion. Euler angles. Eulers equations of motion. torque free motion of a rigid body. heavy symmetrical top. Fast and sleeping top.

4. Small oscillation: Formulation of the problem of small oscillations. The eigen-value equation and the principal axis transformation. Frequencies of free vibration and normal coordinates. Forced oscillations and the effect of dissipative forces.

5. Canonical transformations: Examples. Integral invariants of Poincare. Lagrange and Poisson brackets as canonical invariants. The equations of motion in Poisson bracket notation. Infinitesimal contact transformation. Constants of the motion. Symmetry properties. Angular momentum Poisson bracket relations. Liouvilles theorem.

6. Hamilton-Jacobi (HJ) theory: Hamilton-Jacobi equations for Hamiltons principal and characteristic functions. The harmonic oscillator problem by Hamilton-Jacobi method. Separation of variables in the Hamilton-Jacobi equation. Action-angle variables. Periodic motion.The Kepler problem in action-angle variables. Passage from classical to quantum mechanics.

7. Continuous system and fields: Clasical Lagrangian and Hamiltonian density, equation of motion, conservation theorems.

Quantum Mechanics I

1. Reviews of introductory discussions on Schrodinger equation and relevant topics.

2. Formalism of quantum mechanics. Axiomatic definition. Vector spaces; linear independence, bases, dimensionality. Inner product, Gram-Schmidt orthogonalisation. Linear operators. Representation of linear transformations and change of base. Eigenvalues and eigenvectors. Functions of a matrix. Cayley-Hamilton theorem. Commuting matrices with degenerate eigenvalues. Orthonormality of eigenvectors.

   Hilbert space. Kets, bras and operators, Base kets and matrix representation. Hermitian operator. Eigenkets as base kets. Orthogonality.The superposition and completeness of eigenstates. Postulates of quantum mechanics. Observable and results of its measurement. The generalized uncertainty relation. Expectation values of dynamic variables. Commutators and operator algebra. Non-commutating observables. Complete set of commuting observables. Change of basis. Unitary operators Discrete and continuous bases. Coordinate and momentum representations. Quantum Dynamics. Schrodinger, Heisenberg and interaction pictures. Evolution operator. Linear harmonic oscillator by Schrodinger equation, Heisenberg equation and Dirac operator method. Coherent states.

3. Time-independent Schrodinger equation in one dimension. The free particle. The infinite square well. The delta-function and periodic delta function potential. The finite square well. Transmission coefficient.
   Schrodinger equation in three dimensions. Schrodinger equation in spherical coordinates. Orbital angular momentum. Eigenvalue problem for angular momentum. Spherical harmonics. The rigid rotator. The spherical well with impenetrable walls. Spherical square well potential. Coulomb potential. The hydrogen atom problem. Parity of wavefunctions.

4. Approximation methods. Time-independent perturbation theory for non-degenerate and degenerate states. Applications to anharmonic oscillator, Stark effect in hydrogen atom.
   Variational methods. Application to the ground state of delta function potential, helium atom, Hydrogen molecule ion.
   The WKB approximation. General form. Application to the theory of alpha decay. Connection formulas.

5. Time-dependent perturbation theory. Constant and harmonic perturbations. Fermis golden rule. Sudden and adiabatic approximations. Interaction of an atom with electromagnetic wave. Transition probability and Electric dipole radiation.

6. Identical particles. Symmetry under interchange. Wave functions for bosons and fermions. Slater determinant.

Classical Electrodynamics

1. Review of electrostatics and magnetostatics: Formal solution of the electrostatic boundary value problem with Greens function. Boundary value problems. Multipole expansion of fields and potentials. Electrostatics of macroscopic media.

2. Electromagnetic induction: Fundamental equations. Maxwells equations. Electromagnetic waves in conducting and nonconducting media. Frequency dependence of permitivity. wave guides.

3. Potentials and fields: Gauge transformations Lorentz and Coulomb gauges; Poynting vector. The inhomogeneous wave equation - Greens function, retarded and advanced potentials. Fields and radiation of a localized oscillating source. Multipole expansion of scalar and vector potentials; radiation fields, dipole radiation. Lienerd-Weichert potentials; the fields of a uniformly moving charge. Radiation from an accelerated charge. Angular distribution of the emitted radiation; Larmors formula and its relativistic generalization; special cases of acceleration; parallel and perpendicular to velocity. Bremsstrahlung, Cerenkov radiation, radiation reaction.

4. Relativistic Electrodynamics: Tensors in minkowski space, Electromagnetic field tensor, Covariance of electrodynamics, Transformation of electromagnetic field. Relativistic Lagrangian and Hamiltonian and Hamiltonian of a charged particle in an electromagnetic field. Lagrangian for electromagnetic field; stress tensors, conservation laws

5. Scattering from a free electron. Thomson scattering. Scattering from a bound electron. Rayleigh scattering. Absorption of radiation by a bound electron. Normal and anomalous dispersion. Lorentz electromagnetic theory.

Statistical Mechanics

1. Scope and aim of statistical mechanics. Transition from thermodynamics to statistical mechanics. Review of the ideas of phase space, phase points, and ensemble. Density of phase points. Liouvilles equation and Liouvilles theorem.

2. Stationary ensembles: Micro canonical, canonical and grand canonical ensembles. Partition function formulation. Fluctuations in energy and particle number. Equilibrium properties of ideal systems: ideal gas, Harmonic oscillators, rigid rotators. Para magnetism, concept of negative temperature.

3. Density matrix: Idea of quantum mechanical ensemble. Statistical and quantum mechanical approaches. Pure and mixed states. Density matrix for stationary ensembles. Application to a free particle in a box, and an electron in a magnetic field. Density matrix for a beam of spin 1/2 particles. Construction of the density matrix for different states (pure and mixture) and calculation of the polarization vector.

4. Distribution functions. Bose-Einstein and Fermi-Dirac statistics. General equations of state for ideal quantum systems.

5. Ideal quantum systems: (a)Properties of ideal Bose gas. Bose-Einstein condensation. Transition in liquid He4, Superfluidity in He4. Photon gas. Plancks radiation law. Phonon gas. Debyes theory of specific heat of solids. (b) Properties of ideal Fermi gas: Review of the thermal and electrical properties of an ideal electron gas. Landau levels, Landau diamagnetism. White dwarf and Neutron stars.

6. Strongly interacting systems. Ising model. Idea of exchange interaction and Heisenberg Hamiltonian. Ising Hamiltonian as a truncated Heisenberg Hamiltonian. Exact solution of one-dimensional Ising system (Matrix method). Bragg-Williams approximation (Mean field theory) and the Bethe-Peierls approximation.

7. Phase transition: General remarks. Ehrenfest's classification, Phase transition and critical phenomena. Critical indices. Landaus order parameter theory of phase transition.

8. Thermodynamic fluctuations. Spatial correlations in a fluid. Brownian motion: Einstein-Smoluchowskis theory.

Relativity and Nonlinear Dynamics

1. Special Theory of Relativity: Lorentz transformation; Dopler effect, 4-vector(time space and light like), 4-velocity and acceleration; 4-momentum and force. Minkowski space and metric. Relativistic invariants and kinematics: Decay, elastic collision and reaction. Lagrangian formulation of relativistic mechanics. covariant Lagrangian formulation.

2. General theory of relativity: Review of tensor analysis. inclination of two vectors orthogonality, areas and volumes, raising and lowering of indices, Christoffel symbols and teir transformations; intrinsic and covariant differentiations, Riemann Christoffel tensors, Bianchi identities, curvature tensors, differential equation of geodesics, parallel transports, anti-parallel curves, condition of flatness, Ricci tensor, Einstein tensor. Inconsistence of Newtonian gravitation with special theory of relativity; principles of equivalence and general covariance; Einsteins field equations; Schwarzschild solution; geodesics of Schwarzschild solution; singularity, event horizon and black holes, Birkhoffs theorem; experimental tests- perihelion motion of a planet, bending of light and gravitational red shift;

3. Nonlinear Dynamics:

   Idea of Nonlinearity. Framework for the study of dynamics in state space. Autonomous and nonautonomous systems. The no-intersection theorem. Dissipative systems and attractors. One-dimensional state space. Fixed points and stability. Linearization near fixed points. Lyapunov exponent. Trajectories in a one-dimensional state space. Phase portrait.

4. Two-dimensional state space. Brusselator model. Dynamics and complex characteristic values. Dissipation and the divergence theorem. Jacobian matrix for characteristic values. Limit cycles. Poincar sections and the stability of limit cycles. Poincar-Bendixson theorem.

5. Bifurcations. Saddle-node and repellor-node bifurcations. Supercritical and subcritical pitchfork bifurcations. Bifurcations in two dimensions. Limit cycle bifurcations. Hopf bifurcation.

6. Three-dimensional state space. Routes to chaos. Period doubling. Quasi-periodicity. Intermittancy.

Lorenz model, Simple properties of the Lorenz equations, Introduction to chaos. Lyapunov exponents.

Quantum Mechanics II

1. Generalised angular momentum. Infinitesimal rotation. Generator of rotation. Commutation rules. Matrix representation of angular momentum operators. Spin. Pauli spin matrices. Eigenspinors. Electron in static magnetic field. Larmor precession. Electron in an oscillating magnetic field. Addition of two angular momenta. Simple examples. Clebsch-Gordan co-efficients. Recursion relations.

2. Discrete and continuous space-time symmetries. Invariance principles and conservation laws. Space translation. Time translation. Space rotation. Irreducible spherical tensor operators. Wigner-Eckert theorem. Space inversion. Time reversal. Kramers degeneracy.

3. Scattering theory. Scattering amplitude. Differential and total cross sections. Integral equation for potential scattering. Greens function. Born approximation and its validity. Yukawa potential. Rutherford scattering formula. Method of partial waves. Phase shifts. Optical theorem. Scattering by a hard sphere.

4. Relativistic quantum mechanics. The Klein-Gordon equation. Covariant notation. Probability density. Negative energy solution. The Dirac equation. Properties of the Dirac matrices. The Dirac particle in an electromagnetic field. The spin and magnetic moment of the electron.

5. Covariant form of the Dirac equation. Lorentz covariance. Rotation, parity and time reversal operations on the Dirac wavefunction. The γ_5 matrix and its properties. Plane wave solutions of the Dirac equation and their properties. Energy and projection operators. Diracs hole theory.

6. Non-relativistic limit of the Dirac equation. Large and small components. Spin-orbit interaction from Dirac equation. Foldy-Wouthuysen transformations for a free particle and for a particle in a field. Electon in a central electrostatic potential.

7. Concept of field. Lagrangian dynamics of classical fields. Euler-Lagrange equation. Lagrangians and equations of motion of fundamental fields. Noethers theorem. Conserved currents and charges. Energy-momentum tensor and energy of fields. Introductory idea about second quantization. Example-Schrödinger equation

Electronics

1. Networks: Review of network theorems. Driving point impedance and admittance, Fosters reactance theorems. Canonic networks. Filter circuits. Active and passive filters. LPF, HPF, BPF and BRF type constant-k prototype filters. Attenuators.

2. Transmission line theory: Distributed parameters. Primary and secondary line constants; Telegraphers equation. Reflection co-efficient and VSWR. Input impedance of loss-less line. Distortion of em wave in a practical line. Smith chart.

3. Semiconductor physics: Carrier concentration. Fermi levels of intrinsic and extrinsic semi-conductors. Bandgap. Direct and indirect gap semiconductors. p-n junction physics. Junction breakdown. Hetero-junction. Characteristics of some semiconductor devices: LED, Solar cell, Tunnel diode, Gunn diode and IMPATT. SCR; Unijunction transistor (UJT). Programmable Unijunction transistor (PUT).

4. Active Circuits: Transistor amplifiers. Basic design consideration. High frequency effects. Video and pulse amplifier. Tuned amplifier. Nonlinear amplifiers using op-amps. regenerative comparators. Precision rectifiers. Op-amp based function generators.

5. Communication electronics: Principles of analog modulation- linear and exponential types. Generation of transmitted carrier and suppressed carrier type AM signals. Principles of FM and PM signal generation. Principles of detection modulated signals. Modulation techniques in some practical communication systems. AM and FM radio.

6. Digital circuits: Logic simplification using Karnaugh maps. SOP and POS design of logic circuits. Multiplexure and demultiplexure. RS, JK and MS-JK flip-flops. transformation of flip-flops. Registers and counters. design of counters. ADC and DAC circuits. Basics of Microprocessors and microcontrollers

Condensed Matter Physics

1. Crystalline and amorphous solids: The crystal lattice. Basis vectors. Unit cell. Symmetry operations. Point groups and space groups. Plane lattices and their symmetries. Three dimensional crystal systems. Miller indices. Studdy of some simple crystal structures. X-ray diffraction. Laue theory. Braggs law. Reciprocal lattice. Atomic scattering factor. Experimental methods of x-ray diffraction. Comparative study of X-ray, neutron and electron diffraction.

2. Types of bonding: The van der Waals bond. Cohesive energy of inert gas solids. Ionic bond. Cohesive energy and bulk modulus of ionic crystals. Madelung constant. The covalent bond. Metallic bond.

3. Vibrations of one-dimensional monatomic and diatomic lattices. Infrared absorption in ionic crystals (one-dimensional model). Normal modes of harmonically vibrating solids. Phonons. Frequency distribution function. Debyes theory of lattice specific heat. Anharmonic effects.

4. Quantized free electron theory. Fermi energy, wave vector, velocity and temperature. Density of states in one, two and three dimensions. Electronic specific heat. Pauli spin paramagnetism. Free electron theory of electrical and thermal conductivity. AC conductivity and optical properties. Plasma oscillations. Hall effect. Hall coefficient in one- and two- band models.

5. Magnetic and optical properties of solids: Diamagnetism, Langevin equation. Quantum theory of paramagnetism. Curie law. Hund’s rules. Paramagnetism in rare-earth and iron-group ions. Elementary idea of crystal field effects. Ferromagnetism. Curie-Weiss law. Heisenberg exchange interaction. Mean field theory. Antiferromagnetism. Nel point. Nuclear magnetic resonance. Optical Properties of Solids

6. Energy bands in solids. The Bloch theorem. Bloch functions. Review of the Kronig-Penney model. Brillouin zones. Number of states in the band. Band gap in the nearly free electron model. The tight binding model. Electron dynamics in an electric field. The effective mass. Concept of hole.

7. Superconductivity, Survey of important experimental results. Critical temperature. Meissner effect. Type I and type II superconductors. Thermodynamics of superconducting transition. London equations. London penetration depth. Energy gap. Basic ideas of BCS theory. High-Tc superconductors.

Atomic and Molecular Spectroscopy

Atomic Spectroscopy:

1. Spectra of hydrogenic atoms. Fine structure; Relavistic correction. Spin-orbit interaction, Lamb shift. Spectra of alkali atoms. Quantum defect. Penetrating and non-penetrating orbits. Introduction to electron spin. Relativistic correction to spectra of hydrogen atom. The Lande g factor. Zeeman and Paschen-Back effects. Hyperfine structure in the spectra of monovalent atoms.

2. Spectra of divalent atoms. Singlet and triplet states of divalent atoms. L-S and j-j coupling. Magnetic field effects. Spectra of Many-electron atoms. Pauli exclusion principle. Periodic classification of elements. Equivalent and non-equivalent electrons. Spectral terms of equivalent and non-equivalent electrons for ground and first excited state electronic confugurations.

3. Origin of X-ray spectra. Screening constants. Fine structure of X-ray leveL. Spin-relativity and screening doublet laws. Non-diagram lines. Auger effect.

4. Broadening of spectral lines. Natural width of spectral lines, Doppler broadening.

Molecular Spectroscopy:

5. Born-Oppenheimer approximation and separation of electronic and nuclear motions in molecules. Band structure of molecular spectra. Hydrogen molecule ion. Molecular orbitals. Hydrogen molecule.

Valence bond approach. Coulomb and exchange integrals. Electronic structure of simple molecules. Chemical bonding. Hybridization.

6. Microwave and far infrared spectroscopy. Energy levels of diatomic molecules from rigid and non-rigid rotator models. Selection rules. Structure determination. Isotope effect. Rotational spectra of polyatomic molecules.

7. Infrared Spectra. Harmonic and anharmonic (no deduction) models for vibrational energy levels of diatomic molecules. Selection rules. Morse potential. Energy curves. Dissociation energy. Isotope effect. Rotational-vibrational coupling. Symmetry of molecular wavefunctions and nuclear spin.

8. Raman spectroscopy. Rotational, vibrational, Rotational-vibrational Raman spectra. Stokes and anti-Stokes Raman lines. Selection rules. Nuclear spin and its effect on Raman spectra.

9. Vibrational spectra of polyatomic molecules. Normal modes. Selection rules for Raman and infrared spectra. Normal modes of CO2 and other simple triatomic molecules.

10. Electronic spectra of diatomic molecules. Vibrational band structure. Progressions and sequences. Isotope shift. Intensity distribution in vibrational structure of electronic spectra. Franck-Condon principle. Rotational structure of electronic spectra. P-, Q-, and R- branches. Band head formation. Hund's coupling cases. Pre-dissociation. Inversion spectrum of Ammonia.

Plasma Physics

1. Elementary concepts of Plasma. Occurrence of plasma in nature, Concept of temperature, oncept of Debye shielding, plasma sheath, plasma oscillation, Plasma parameters, Plasma criteria. Applications of plasma physics.

2. Motion' of charged particles in electromagnetic field. Uniform E and B fields, Non- uniform fields. Special variations of magnetic fields, gradient drift, parallel acceleration of guiding center. Magnetic

mirror effect, Time-varying E and B fields. Adiabatic invariants

3. Hydrodynamical description of plasma. Fundamental fluid equations of Plasma, Fluid drift perpendicular to B, Fluid drift parallel to B. Plasma approximation. plasma oscillation. Effect of temperature.

4. Hydromagnetic equilibrium. Concept of . Diffusion of magnetic fields in plasma, Plasma instabilities. gravitational, two stream, Weibel instability.

5. Diffusion and mobility in weakly ionized plasmas. Collision parameters. Ambipolar diffusion coefficient, Recombination. Plasma resistivity.

6. Plasma kinetic theory. Equation of kinetic theory, derivation of fluid equations. Plasma oscillations and Landau damping (qualitative discussion) and resonant particle. Experimental verification of Landau damping.

Computer Application

1. Familiarity with LINUX and programming languages. Elements of Programming Language: Algorithms and flowchart. Structure of a high level language program. Constants and variables. Expressions. Input and output statements. Conditional statements and loop statements. Arrays. Functions.Structures. Pointer data type. List and trees.

2. Numerical techniques: Approximate numbers and Significant digits, Types of errors, General formula for errors, Order of errors.

3. Representation of integers and real numbers. Accuracy. Range. Overflow and underflow of number representation. Error propagation and instability. Solution of polynomial equations - bisection and Newton-Raphson algorithms. Interpolation- Lagrange's interpolation formula. Least square fit. Matrix

addition and multiplication. Numerical differentiation. Numerical integration trapezoidal formula, Simpsons formula.

Advanced Optics

1. Coherence of light. Mutual coherence function. Complex degree of coherence. Quasi-monochromatic fields and visibility. Spatial coherence of ordinary and laser light. Photon statistics. Poissonian photon statistics. Classification of light by photon statistics. Photon statistics of thermal and laser sources. Brown-Twiss correlations. Photon bunching and antibunching.

2. Historical background of laser. Einstein coefficients and stimulated light amplification. Gain and feed-back. Threshold. Photon rate equations. Population rate equations. Population inversion. Creation of population inversion in three level and four level lasers. Small-signal gain and saturation. Pumping processes.

3. Basic Laser Systems. Gas Laser. CO2 laser. Solid State Laser: Host material and its characteristics. Doped ions. Nd:YAG laser. Liquid laser. Dye laser. Semiconductor laser.

4. Nonlinear Optics. Origin of nonlinearity. Nonlinear optical materials. Nonlinear polarization. Nonlinear susceptibilities. Self-focussing. Self-phase modulation. Second harmonic generation. Phase matching. Three-wave mixing. Parametric amplification and oscillation.

5. Fibre optics. Dielectric slab waveguide. Modes in the symmetric slab waveguide. TE and TM modes. Modes in the asymmetric slab waveguide. Coupling of the waveguide (edge, prism, grating). Dispersion and distortion in the slab waveguide. Integrated optics components (active, passive). Optical fibre waveguides (step index, graded index, single mode). Attenuation in fibre. Couplers and connectors. LED. Injection laser diode (double heterostructure, distributed feedback).

6. Detection of optical radiation. Photon detectors (photoconductive, photo voltaic detector and photoe-missive detectors). p-i-n photodiode. APD photodiode.

Astrophysics

1. Introduction: Astrophysics and Astronomy. Celestial coordinate systems (Sun-Earth system, Galactic coordinate system).

2. Stellar Structure and Evolution: (i) Star formation. Stellar Magnitudes. Classification of stars. H-D classification. Sahas equation of ionization. Hertzsprung-Russel (H-R) diagram. (ii) Gravitational energy, Virial theorem, Equations of stellar structure and evolution. (iii) Pre-main sequence evolution, Jeans criteria for star formation, fragmentation and adiabatic contraction, Evolution on the main sequence, Post main sequence evolution, Polytropic Models. Lane-Emden equation. Simple stellar models. Eddingtons model and Homologous model, Convective and Radiative stars, Pre-main sequence contraction: Hayashi and Henyey tracks.

3. Nuclear Astrophysics: Thermonuclear reactions in stars, pp chains and CNO cycle. Solar Neutrino problem. Thermonuclear reactions. Helium burning and onwards. Nucleosynthesis beyond iron, r- and s- processes.

4. Stellar objects and stellar explosions. Brief discussions on: Galaxies, Nebulae, Quasars, Brown dwarfs, Red giant stars, Nova, Supernova.

5. Gravitational collapse and relativistic astrophysics: Newtonian theory of stellar equilibrium. White dwarfs. Electron degeneracy and equation of states. Chandrasekhar limit. Mass-radius relation of WD. Neutron stars. Spherically symmetric distribution of perfect fluid in equilibrium. Tolman-Oppenheimer-Volkoff equation, Mass- radius relations of NS. Pulsars, Magnetars, Gamma ray bursts. Black holes: Collapse to a black hole (Oppenheimer and Snyder), event horizon, singularity.

6. Accretion disks: Formation of accretion disks. Differentially rotating systems in astrophysics. Disk dynamics. Steady disks. Disk formation in close binary systems through mass transfer. Accretion onto compact objects (Black holes and Neutron Stars).

Advanced plasma physics:

1. Theory of plasma waves. Electron plasma waves, sound waves, Ion waves, Comparison of ion and electron wave. Electrostatic wave perpendicular to B and parallel to B , Electrostatic ion cyclotron wave, Electromagnetic wave perpendicular to B and parallel to B. Alfven wave. Derivation of dielectric tensor and dispersion relation for cold uniform magnetized plasma. Cut off and resonance. Mode conversion, acessibility condition, Ray Tracing, Whistlers, Warm plasma modes. Plasma heating method.

2. Magnetohydrodynamic treatment of plasmas. Equilibrium equations, Approximations, magnetic surfaces, surface quantities, Relation among suff
ace quantities, Flux co-ordinates, magnetic field representation. Gard-Shafranov (G-S) equation and examples of G-S solutions. Interchange, Sausage and Kink instabilities.

3. Nonlinear Phenomena: Large amplitude electron plasma oscillation, Exact solution in Lagrangian variable, extension of the model. Derivation Korteweg- de Vries equation for nonlinear sound wave. Solitary wave solution. Nonlinear drift-waves.

General Relativity and Cosmology

1. Review of special theory of relativity: Poincare and Minkowskis 4-dimensional formulation. Geometrical representation of Lorentz transformations in Minkowskis space. Length contraction. Time dilation. Causality. Time-like and space-like vectors. Newtons second law of motion expressed in terms of 4-vectors.

2. Tensor calculus: Idea of Euclidean and non-Euclidean space. Meaning of parallel transport and covariant derivatives. Geodesics and autoparallel curves. Curvature tensor and its properties. Bianchi Identities. Vanishing of Riemann-Christoffel tensor as the necessary and sufficient condition of flatness. Ricci tensor. Einstein tensor.

3. Einsteins field equations: Inconsistency of Newtonian gravitation with the special theory of relativity. Principles of equivalence. Principle of general covariance. Metric tensors and Newtonian Gravitational potential. Logical steps leading to Einsteins field equations of gravitation. Linearised equation for weak fields. Poissons equation.

4. Applications of general relativity: Schwarzschilds exterior solution. Singularity. Event horizon and black holes. Isotropic coordinates. Birkhoffs theorem. Observational tests of Einsteins theory.

5. Gravitational Collapse and Black Holes: Brief discussions on: White dwarfs, Neutron stars, static and rotating black holes (Schwarzschild and Reissner-Nordstrom). Kerr metric (derivation not required), event horizon, extraction of energy by Penrose process. Kerr-Neumann Metric (no derivation). No hair theorem. Cosmic censorship hypothesis.

6. Cosmology: Cosmological principles. Weyl postulates. Robertson-Walker metric (derivation is not required). Cosmological parameters. Static universe. Expanding universe. Open and closed universe. Cosmological red shift. Hubbles law. Olbers paradox. Brief discussions on: Big bang, Early universe (thermal history and nucleosynthesis), Cosmic microwave background radiation, Particle horizon.

Nuclear and Particle Physics

1. General properties of nuclei. Nuclear radius and charge distribution. Charge radius of nucleus from electron scattering experiment and the study of muonic x-rays. Charge form factor. Nuclear binding energy. Semi-empirical mass formulas. Angular momentum and parity of nuclei. Magnetic dipole moment. Electric quadrupole moment and nuclear shape.

2. Two-nucleon problem and nuclear forces. Ground and excited states of deuteron. Two-nucleon scattering. n-p scattering. Partial wave analysis. Phase-shift. Scattering length. Low energy p-p scattering (qualitative discussion). Charge symmetry and charge independence of nuclear forces. Isospin symmetry. Exchange interaction. Elementary discussion on Yukawas theory.

3. Nuclear modeL. Fermi gas model. Extreme single particle models. Spherical shell model. Collective model.

4. Nuclear reactions. Conservation laws. Energetics. Q-value. Spontaneous fission. Mass and energy distribution of fragments. Direct and compound nuclear-reactions. Experimental verification of Bohrs independence hypothesis. Resonance reactions. Breit-Wigner dispersion relation. Stripping and pick up reactions (qualitative discussion only). Optical model.

5. Particle accelerators. Pelletron. Tandem principle. Synchrotron and synchrocyclotron. Colliding beams. Threshold energy for particle production.

6. Beta and Gamma decay. Fermis theory of beta decay. Allowed and forbidden transitions. Selection rules. Non-conservation of parity in beta decay. Detection of neutrino. Gammadecay and selection rules (derivation of transition probabilities not required). Internal conversion.

7. Energy loss of charged particles and gamma rays. Ionization formula, Stopping power and range. Radiation detectors. Multiwire proportional counter. Scintillation counter. Cerenkov detector.

8. Reactor Physics. Slowing down of neutrons in a moderator. Average log decrement of energy per collision. Slowing down power. Moderating ratio. Slowing down density. Fermi age equations. Four-factor formula. Typical nuclear reactors.

9. High energy physics. Types of interaction in nature. Typical strengths and time-scales. Conservation laws. Charge-conjugation. Parity and Time reversal. CPT theorem, Gell-Mann-Nishijima formula. Intrinsic parity of pions. Quark model. Charm, beauty and truth. Gluons. Quark-confinement. Asymptotic freedom.

   Symmetry classification of elementary particles. Weak interactions-different types. Selection rules. Parity violation and CP violation.

Computational Physics

1. Mathematical Methods: Solution of simultaneous algebraic equations, Gauss elimination method, pivoting. Eigenvalues and eigenvectors of a square matrix. Solution of ordinary differential equations, Euler method, Runge-Kutta methods (up to 4th order), finite difference method. Richardson's extrapolation - Romberg's integration. Monte-Carlo integration. Discrete and fast Fourier transforms.

2. Mechanics: Applications to simple mechanical problems, accelerated and circular motions, projectile. Planetary motion, Kepler's laws. Oscillatory motion and waves, beats.

3. Quantum Mechanics: Solution of time-independent Schrodinger equation. Simple three point formula. Numerov's method. Particle in infinite square well, harmonic oscillator, Gaussian wave packet. Perturbation applications, anharmonic oscillator.

4. ELectrodynamics: Potential and field due to point charge and simple charge distributions. Solution of Laplace's and Poisson's equations. Relaxation algorithm. Magnetic field produced by a current. Solenoid.

5. Random Systems: Use of random numbers. Monte-Carlo technique.Applications to Statistical Mechanics. Ising Model, Ferromagnetic to Paramagnetic phase transition. Metropolis algorithm. Random walk problem. Diffusion.

6. Non-linear Dynamics and Chaos: Phase plot and phase trajectories. Bifurcations- saddle node, pitch fork, transcritical Hopf bifurcations. Lorenz equation and study of chaos. Vander pol, Chua and other systems. Chaos in non-linear driven pendulum. Liyapunov exponent. Period doubling route to chaos, bifurcation plot, Poincare section.

7. Introduction to cellular automata and percolation.

Advanced Electronics

1. Analog Circuits: Oscillators and voltage regulatores. Harmonic self-oscillators. Steady state operation of self-oscillator. Nonlinear equation of self-oscillator. Op-amp based self-oscillator circuits. RC phase shift, LC, Wien bridge, Non-sinusoidal oscillators. Line and load regulation. Zener, op-amp, IC, Switching regulators. OP-AMP comparator. Multivibrator and timing circuits. IC 555 based timing circuits.

2. Communication Principle: Review of CW Modulation Technique: Linear modulation DSB, SSB, VSB, QAM techniques, Exponential modulation FM and PM; AM and FM modulators and demodulators. Pulse and digital modulation tecnique. Principles of ASK, FSK, PSK, DPSK.

   Specialised Communication Systems: Basics of Satellite Communication. Orbits, Station keeping. Satellite attitude. Path loss calculation. Link calculation. Multiple access techniques.

3. Optoelectronics: Classification and fabrication principles of optical fibres. Wave propagation in optical fibre media. Losses in fibre. Optical fibre source and detector, Optical joints and Coupler, Fibre characteristics. Basic principles of optical fibre communication. Power budget equation; Multiplexing. Quantum limit. Signal-to-noise ratio calculation.

4. Antenna and Radar System: Basic Considerations. antenna parameters. current distributions. short electric doublet. half wave dipole. longer antenna. effect of ground; image antenna; Field strength at a point close to the antenna; microwave antenna and other direc- tional antennas. Basic pulsed radar system modulators, duplexer indicators, radar antenna CW radar.

5. Design of combinational and sequential circuits: registers, counters, gate arrays. Programmable logic devices PAL, GAL, PLA. Programmable gate arrays.

6. Memories: Sequential and Random access memories. RAM bipolar and MOS static and dynamic memories. Programmable memories: PROM, EPROM, EEPROM.

7. Microprocessors and their applications. Architecture of 8 bit (8085) and 16 bit (8086) microprocessors. Addressing modes and assembly language programming of 8085 and 8086. Machine cycles and their timing diagrams. Interfacing concepts. Memory and I/O interfacing. Interrupts and interrupt controllers. Microprocessor based system design.

RET SYLLABUS
ON
RESEARCH METHODOLOGY

UNIVERSITY OF GOUR BANGA

DEPARTMENT OF PHYSICS

Details of the Courses:

Paper -1.*Research Methodology (RM)*General

Mode of study includes: Assigning the topic to students based on their basic background and presentation in the form of seminar which will be followed by discussion and submission of thewrite-up. This will be evaluated by group of teachers. There will not be any formal classroomteaching.

INTRODUCTION :

Brief History of Scientific thoughts, Motivation and De-Motivation for Research Definition of Research, Qualities of Researcher, Identification of the Problem, Various Steps in Scientific Research,Hypothesis and axiomatic-deductive systemsResearch Purposes, Research Design, Literature survey – Mode of approach of actual investigation – Abstraction of a research paper

DESIGN AND PLANNING:

Internet and its applications – ***e-journals***- Assessing the status of the problem – Results and Conclusions – Presenting a Scientific seminar – Publication of Research paper - Importance of reproducibility of research work.

DATA COLLECTION:

Sources of Data: Primary Data, Secondary Data; Sampling Merits andDemerits of Experiments, Procedure and Control Observations, Sampling Errors - Type-I, Error - Type-II,

STATISTICAL ANALYSIS AND FITTING OF DATA :

Introductory probability and stochastic processes.,Conditional Probability, Poisson Distribution, Binomial Distribution and Properties of NormalDistributions, Estimates of Means and Proportions; Chi-Square Test, Association of Attributes - t-Test -Standard deviation - Co-efficient of variations.Correlation and Regression Analysis, Descriptive statistics and correlations,Introduction to GnuPlot and Sage/Mathematica/Matlab/Origin.

SCIENTIFIC WRITING :

Structure and Components of Research Report, Types of Report: researchpapers, thesis. Research Project Reports, Pictures and Graphs, citation styles,Scientific ethics, copyrights and plagiarism

References:

1. C. Anderson, B.H. Durston and M. Poole, Thesis and Assignment writing (Wiley Eastern, New Delhi, 1977).
2. “How to Research”by Loraine Blaxter, Christina Hughes and Malcum Tight, (Viva Books).
3. .R. Kothari, Research methodology: Methods and Techniques, (New age International, New Delhi, 2006).
4. Internet: An Introduction, CI Systems School of Computing, Jaipur (Tata McGraw Hill, New Delhi, 1999).
5. “How to write and Publish” by Robert A. Day and Barbara Gastel, (Cambridge University Press).
6. 6. “Probability and Statistics for Engineers and Scientists” by Sheldon Ross, (Elsevier Academic Press).

Paper -1.**Research Methodology (RM)*****Subject Oriented***

Familiarities with and general scientific concepts on basic Theoretical Physics and Experimental Physics (already studied in the UG & PG levels).