POST GRADUATE CBCS SYLLABUS

Department of Physics

Raiganj University

(Introduced from the Current Session 2017-18)

Semester I **Course I – Physical Mathematics: 50(40+10)** **Course II – Classical Mechanics & Special Relativity: 50(40+10)** **Course III – Electronics I: 50(40+10)** **Course IV – Computational Methods and Programming: 50(40+10)** **Course V – Laboratory Course I (Electronics): 100 (65+35)** **IDC-1(Inter disciplinary Course-1) – Computational Methods and Programming –I , Liquid Crystals : 100 (75+25)** **Internal = 10x4+35= 75** **IDC internal: 25** **Total internal Marks=100** **Final Exam. = 40x4 +65+75 = 300** **Grand Total = 400=32 Credits.**	**Semester II** **Course VI – Electrodynamics & Plasma Physics: 50(40+10)** **Course VII – Statistical Mechanics: 50(40+10)** **Course VIII – Quantum Mechanics I: 50(40+10)** **Course IX – Laboratory Course II (Programming): 50(40+10)** **Course X –Comprehensive viva voce (Internal Assessment): 100 (65+35)** **IDC-2(Inter disciplinary Course-2) Computational Methods and Programming –II , Fundamental Electronics: 100 (75+25)** **Internal = 10x4 + 35 = 75** **IDC internal: 25** **Total internal Marks=100** **Final Exam. = 40x4 +65+75 = 300** **Grand Total = 400=32 Credits.**
Semester III **Course XI– Quantum Mechanics II: 50(40+10)** **Course XII – Condensed Matter Physics I: 50(40+10)** **Course XIII – Nuclear and Particle Physics I: 50(40+10)** **Course XIV – Atomic and Molecular Physics: 50(40+10)** **Course XV - Laboratory Course III: 100 (65+35)** **Course XVI – Viva, Seminar & Group Discussion (Internal Assessment): 100 (25+50+25)** **Total Internal Marks = 10x4+35= 75** **Course XVI : Internal = 25** **Final Exam. = 40x4 + 65 +75= 300** **Grand Total = 400=32 Credits.**	**Semester IV** **Course XVII – General Relativity & Astrophysics: 50 (40+10)** **Course XVIII – Special Paper I: 75 (55+20)** **Course XIX – Special Paper II: 75 (55+20)** **Course XX – Laboratory Course IV: 100 (65+35)** **Course XXI – Project/ Field Studies/ Book Reviews (Internal Assessment): 100 (85+15)** **Internal = 10 + 20x2+35+15 = 100** **Final Exam.= 40+55x2+65+85=300** **Grand Total = 400=32 Credits.**

NOTES:

1. Total marks 1600 (total credit 128) is distributed equally in four semesters. Total marks and credit have been mentioned.
2. Special papers at present: (i) Condensed Matter Physics, (ii) Nuclear and Particle Physics, and (iii) Electronics. At present only Nuclear and Particle Physics has been offered due to shortage of faculty members.
3. IDC 1 & IDC 2 has been included in 1st and 2^{nd} semester.
4. Seminar etc. and Project etc. have been included in 3^{rd} and 4^{th} Semester.
5. Only Computational Methods and Programming – I for IDC 1 will be followed in semester I.
6. Only Computational Methods and Programming – II for IDC 2 will be followed in semester II.

Semester I

Course – I: Physical Mathematics

Complex analysis - Functions of complex variables, regular and singular points. Cauchy – Riemann equations. Cauchy's theorem and consequences, integral formulae. Expansion of functions about regular and singular points. Residue theorem - its application in evaluating integrals and series summations.

Partial differential equations and integral transforms - Separation of variables for second order partial differential equations. Integral transforms - Fourier and Laplace transforms.

Differential equations and special functions - Series solution of linear second order differential equations; Legendre, Bessel, Hermite and confluent hypergeometric equations. Dirac's delta function; Gamma and Beta functions; Legendre and associated Legendre polynomials - spherical harmonics; Hermite and Laguerre polynomials.

Linear vector space and matrices - Definition of vector space; dimension, basis, subspace; inner product, orthogonality and completeness. Linear operators - representation of operators by matrices. Matrices - inversion, eigenvalue problem; Normal, orthogonal, Hermitian and unitary matrices. Diagonalization of matrices.

Tensors - Covariant, contravariant and mixed tensors. Tensor algebra, contraction, quotient law. Kronecker delta, Levi-civita symbol and metric tensors. Christoffel symbols and covariant derivative of tensors.

Group theory - Introduction, group multiplication table, discrete and continuous groups. Reducible and irreducible representation of groups, equivalent representation, representation by unitary matrices, Schur's lemma, orthogonality theorem. Rotation groups, unitary groups and Lorentz homogeneous groups.

Green's function - Nonhomogeneous boundary value problem and Green's function, eigenfunction expansion of Green's function, Fourier transformation method of constructing Green's function, application to physical problems.

Course – II: Classical Mechanics and Special relativity

Lagrange's and Hamilton's Principle: Principle of virtual work and D' Alembert's principle; constraints, generalized coordinates and Lagrange's equation of motion. Elements of calculus of variation, applications; Hamilton's principle; principle of least action; Lagrange's equations for non-holonomic and dissipative systems; generalized momenta; phase space and configuration space; symmetry and conservation theorems.

Two-body central force problem: Central force; definition and characteristics; effective potential technique; graphical analysis.

Rigid body kinematics: Kinematics of rigid body motion; degrees of freedom; Euler angles; The Cayley-Klein parameters and spinors; infinitesimal rotation and pseudo vector; rotating frame and pseudo forces; torque free motion of a rigid body; heavy symmetrical top.

Hamilton's equations: Legendre transformation and derivation of Hamilton's canonical equations; derivation of canonical equations from a variational principle; Routhian and Routh's procedure.

Canonical transformations: Equation of canonical transformation, generating functions, Lagrange and Poisson brackets (PB); canonical invariance of Poisson brackets; equation of motion in PB notation; infinitesimal canonical transformation and constants of motion, angular momentum PB relations; Liouville's theorem.

Hamilton Jacobi theory: H-J equation, separation of variables; Hamilton's principal and characteristic functions; action angle variables.

Small oscillations: Stable and unstable equilibria; small oscillations; the eigen value equation and the principal axis transformation for oscillatory systems; frequencies of free vibration and normal co-ordinates; vibration of linear tri-atomic molecule.

Continuous systems: Transition from a discrete to a continuous system; Lagrangian formulation of continuous systems and fields; Hamiltonian formulation; applications,

Special relativity:

Postulates of relativity and Lorentz transformations; kinematical consequences; covariant four dimensional formulation; Minkowski space and metric; relativistic momentum; mass energy equivalance; 3-force and Minkowski force; Lagrangian formulation of relativistic mechanics; covariant Lagrangian formulation.

Course – III: Electronics I

Transistors: JFET, BJT, MOSFET and MESFET- structure, working, derivation of the equations for I-V characteristics under different conditions. High-frequency limits. LED, UJT, SCR and other pn-pn devices-structure and working principle.

Basic small signal amplifiers: Classification of amplifiers, BJTIFET amplifier circuits, model and generalised amplifier circuits, Bootstrapped and Darlington amplifier circuit. Audio power amplifiers. Audio power amplifier requirements, Class A, Class B and Class C power amplifiers, Push pull and tuned power amplifiers. Cascade amplifiers, Diffference amplifiers, Multistage R-C coupled amplifiers. Noise in electronic circuits.

Feedback in amplifiers: General properties offeedback amplifiers, types of feedback and their effect on impedance levels. Practical feedback amplifiers using BJT, FET and OP-AMP.

Oscillators: Feedback sinusoidal oscillator and condition of oscillation, Phase-shift oscillator, Wien bridge oscillator and Multivibrator using BJTIFET; Negative resistance oscillator.

Power supplies and Electronic regulators: Electronic voltage regulators, variable voltage supplies using SCR, IC etc.

OP AMP: Differential amplifiers, DC and AC analysis, CMRR, constant current bias level translator.

Block diagram of a typical OP-AMP circuit: Open-loop configuration. Practical OP AMP: Input offset voltage and current, input bias current, total output offset voltage, CMRR and frequency response Inverting and non-inverting amplifiers. OP AMP with negative feedback - voltage series feedback. Effect of feedback on closed loop gain, input resistance, output resistance, bandwidth, offset voltage and current, voltage follower.

Mathematical Operations: DC and AC amplifier, circuits for summing, scaling, integrator and differentiator, log, antilog and other mathematical operations. Solution of second-order differential equations.

Special circuits using OP AMP: Comparators, square wave and triangle wave generators, voltage regulators, fixed and adjustable voltage regulators, switching regulators, active filters.

Digital Electronics: Number system and codes, logic gates, Boolean algebra and Karnaugh maps. Standard representation for logical functions, Karnaugh map representation of logical functions, simplification of logical functions using K-map, minimization of logical functions specified in Minterms/Maxterms or truth table, Don't care conditions, X-OR and X-NOR simplification of K-maps, five and six variable K-maps.

Arithmetic logic units: Adder, subtractor, signed binary numbers, 2's complement adder, subtractor.

Flip flops: RS latches, level clocking, edge-triggered D flip flops, edge-triggered JK flip flops, JK master-slave flip flops.

Networks and lines: Mesh and node analysis, network impedances, network theorems. Resonant cirrcuits, inductively coupled circuits, reflected impedance. Passive filter circuits. Elementary theory of transmission lines and wave guides.

Course – IV: Computational Methods and Programming

Introduction: Fundamentals of a computer and its working principle; different number systems; representation of integer and real numbers; ASCII codes.

Programming: Instructions to a computer; machine language; high level language; different programming languages; Interpreter and compiler; overview of FORTRAN language; input-output statements; mathematical assignment statements; control statements; function and subroutine subprogrammes; subscripted variables; string variables; files.

Approximations and errors in computing: Introduction; data errors; round off errors; truncation errors; modeling errors; significant digits; absolute and relative errors; general formula of errors; error estimation.

Interpolation: Newton's formulas; Lagrange's interpolation; inverse interpolation.

Numerical differentiation and integration: Numerical differentiation; numerical integration - Simpson's, Weddle's and trapezoidal rules; Gauss' quadrature formula; accuracy of quadrature formulas.

Solutions of algebraic and transcendental equations: Bisection method; method of regula falsi; Newton-Raphson method; secant method; method of iteration; simultaneous equations; roots of a polynomial; synthetic division method; Bairstow's method for complex roots.

Solutions of linear simultaneous equations: Gauss elimination method; Gauss-Jordan method; LV decomposition method; matrix inversion method; Round off errors and refinement; method of iteration.

Eigenvalues and eigenvectors of matrices: Power and Jacobi method

Solution of differential equations: Euler's and Picard's methods; Milne's method; Runge - Kutta method; Multistep method; solution of second order differential equations.

Methods of least squares: Fitting of experimental data; least squares method; fitting of linear, polynomial and transcendental equations.

Random numbers: Properties of random numbers; generation of random numbers; Monte Carlo evaluation of integrals.

Course– V: Laboratory Course I

(List of experiments should be regarded as suggestive of the standard and may not be strictly adhered to. New experiments of similar standard may be added and old experiments may be deleted whenever felt it necessary)

1. To design and construct a stabilized power supply (Constant Voltage Source) using discrete devices and to study the variation of load voltage with load current. Show also the variation of load voltage with load current using IC 78XX.
2. To design and construct constant – K type (a) low pass (b) high pass (c) band pass filters (using π section) and to study the variation of attenuation and phase constants of these filters with input frequency. To determine the cut off frequencies and to compare with theoretical values.
3. To study the variation of output voltage with frequency and load resistance for a given class-B Push Pull amplifier and to obtain the variation of output power with frequency and load resistance.
4. To design and construct clipping and clamping circuits using diodes and to study the variation of output amplitude and wave form using CRO.
5. To design an astable multivibrator using BJT and to study its output waveform and frequency for various RC values. To study how the output can be converted to a square wave using clipping circuit.
6. To design a Uni-junction Transistor circuit and draw its characteristic curves for different values of supply voltage. Use it as a saw - tooth wave generator and determine the frequency of oscillation.
7. To design a circuit diagram and study the voltage gain, input impedance, and power gain of an emitter follower.

8. To study the artificial transmission line (TL) at low frequency (<<1kHz) and to determine the line parameters of the given TL.
9. To construct using OPAMP, (i) Differentiator (ii) Integrator (iii) adder-subtractor circuits. To study their performance for different time varying inputs.
10. To determine CMRR, input offset voltage, output offset voltage, input bias current and slew rate of an OP- AMP.
11. To study OP-AMP as voltage comparator. Plot a curve in input and output voltages and show how the output switches from positive to negative value.
12. To design and construct a Wein-Bridge oscillator using OPAMP and to study its output waveform and frequency for various RC values.
13. To study OP-AMP as a function generator, i.e. as (a). square wave generator (b). triangular wave generator.
14. To construct Half-Adder and Full-Adder circuits using logic gates and to perform some simple 2's complement Adder-Subtractor operations (Two decimal digits).
15. (a) To construct X-OR gate using NAND gates and to verify truth table.
    (b) To convert two input NAND gate to two input OR gate.
    (c) To construct NOR gate by using other gates and hence verify the truth table.

Semester II

Course – VI: Electrodynamics and Plasma Physics

1. Maxwell's equations, dual field tensor, wave equation for vector ·and scalar potentials and its solution, retarded potential and Lienard-Wiechert potential. Radiation fields, radiated energy and application to linear antenna, Hertz potential and dipole radiation fields, multipole radiation fields. Electric and magnetic fields due to a uniformly moving charge and an accelerated charge, linear and circular acceleration and angular distribution of radiated power, Bremsstrahlung, synchrotron radiation and Cerenkov radiation, reaction force of radiation.
2. Motion' of charged particles in electromagnetic field: Uniform E and B fields, nonuniform fields, diffusion across magnetic fields, time-varying E and B fields. Adiabatic invariants: first, second and third adiabatic invariants.
3. Elementary concepts: Derivation of moment equations from Boltzmann equation, plasma oscillations, Debye shielding, plasma parameters, magnetoplasma, plasma confinement.
4. Hydrodynamical description of plasma: Fundamental equations. Hydromagnetic waves; magnetosonic and Alfven waves.

5. Wave phenomena in magnetoplasma: Polarisation, phase velocity, group velocity, cutoffs, resonance for electromagnetic wave propagating parallel and perpendicular to the magnetic field, propagation at a finite angle and CMA diagram. Appleton- Hartree formula and propagation through ionosphere and magnetosphere: helicon, Whistler modes and Faraday rotation.

Course – VII: Statistical Mechanics

Introduction: Phase space; density of distribution; Liouville's theorem.

Statistical equilibrium and thermodynamics: Ensembles; ensemble averages, conditions for statistical equilibrium; thermodynamic functions; Ideal classical gas; partition function; relation to thermodynamic quantities.

Fluctuations: Ergodic and quasi-ergodic systems; fluctuations; energy and density fluctuations; critical opalescence.

2. Classical statistics: Maxwell-Boltzmann distribution; principal of equipartition; inadequacy of classical theory.

3. Density matrix and its properties: Ensembles and grand ensembles in quantum statistics; equilibrium properties of a system of ideal gases in micro canonical and grand canonical ensembles .

4. Bose-Einstein statistics: Application to photons; Planck's formula; Bose-Einstein condensation; liquid Helium II.

5. Fermi-Dirac statistics: Degenerate Fermi gas.

Some applications: Specific heats of diatomic gases and crystalline solids; chemical equilibrium; thermal ionization; imperfect gases. Cluster and cluster integrals; The second viral coefficient; van der Wall's equation; cluster expansion of the equation of state of real classical gas.

Irreversible processes: Onsager's relations; applications.

Elements of lattice statistics: Ising model.

Course – VIII: Quantum Mechanics I

1. General formalism - States, observables and operators in quantum mechanics, Dirac's notation, measurement, eigenstates and mixed states, expectation values, wave-packets, Ehrenfest's theorem. Basic postulates, uncertainty principle, Schrodinger's equation, co-ordinate and momentum representation. Schrodinger, Heisenberg and interaction picture, Heisenberg's equation of motion.

2. Eigenvalue problems - Schrodinger's method: stationary states, solutions for one dimensional problems; linear harmonic oscillator, angular momentum, hydrogen like atom. Matrix method: linear harmonic oscillator, angular momentum, Pauli's spin-1/2 matrices.

3. Approximation methods - Time independent perturbation theory - non-degenerate and degenerate cases, application to one-electron atom. Time dependent perturbation theory, transition probability, Fermi's golden rule, application of time dependent perturbation theory. WKB method, quantization rule, connection formula, application to tunneling through a barrier. Variational method, application to H and He-atom, Ritz principle for excited states.

Course – IX: Laboratory Course II (Programming)

(List of programming problems should be regarded as suggestive of the standard and may not be strictly adhered to. New problems of similar standard may be added and old problems may be deleted whenever felt it necessary)

1. Programming on solution of nonlinear equations by various methods.
    a. Root within an interval using Bisection Method
    b. Root within an interval using False position Method
    c. Root near a given point by Newton-Raphson Method
    d. Finding multiple roots through incremental search
    e. Finding multiple roots through synthetic division
    f. Finding complex roots through Baristows Method
2. Programming on solutions of system of linear equations through
    a. Jacobi iteration method
    b. Gauss Seidal method and method of relaxation
3. Programming on interpolation methods.

    Finding the Interpolation value at a point, given a set of table points, using
    a. Lagrange interpolation representation
    b. Newton interpolation representation
    c. Natural cubic spline interpolation
4. Curve fitting and regression
    a. Fitting a straight line to a set of data points using method of least squares
    b. Fitting a polynomial curve to a set of data points using method of least squares
5. Problems on numerical differentiations.
    a. Writing programs to evaluate a given function at various points of interest and estimate its first and second derivatives at any specified point.
    b. Newton's interpolation and other Methods.
6. Problems on numerical integrations by different methods.
    a. Integrating a given function using Trapezoidal rule
    b. Integrating a given function using Simpson's 1/3 rule
    c. Integrating a given function using Weddle's rule
    d. Integrating a given function using Gaussian quadrature method

7. Programming on numerical solution of ordinary differential equations.
    a. using Euler's method
    b. using Runge-Kutta method
8. Solution of linear systems of equations through matrix methods
    a. Solution of linear systems by determinants
    b. Solution of linear systems through matrix inversion
9. Boundary value and Eigenvalue problem
    a. Determination of coefficients of characteristic polynomial by Fadeev-Leverrier Method.
    b. Determination of Eigenvectors of a system of linear equations .
    c. Finding eigenvalue and corresponding eigenvector using power method.
10. Problems on Monte Carlo Technique
    a. Generation of random numbers and
    b. Monte Carlo evaluation of integrals.

Course – X: Group Discussion

Semester III

Course – XI: Quantum Mechanics II

1. Symmetries - Symmetries and conservation laws in quantum 1!1echanics, continuous symmetries, space and time translation, rotation, rotation groups, infinitesimal transformation and Lie groups, Wigner-Eckart theorem, discrete symmetries, parity and time reversal.

2. Angular momentum - Orbital and spin angular momenta, spin matrices and spinors. Addition of angular momenta, Clebsch-Gordon coefficients.

3. Many particle system - Identical particles, exchange degeneracy, symmetrization postulate, symmetric wave function and bosons, asymmetric wave function and fermions, Pauli's exclusion principle, BE and FD statistics, second quantization formalism, one and two particle operators in second quantization formalism.

4. Scattering theory - Partial wave analysis, phase shift, applications, Coulomb scattering, Green's function in scattering theory, Born approximation.

5. Relativistic quantum mechanics - Lorentz group, Klein-Gordon equation, Dirac equation and its plane wave solution, spin and magnetic moment of an electron, negative energy states and its interpretations, covariance of Dirac equation, construction of covariant quantities, large and small

components, Pauli's theory as non-relativistic approximation, higher order corrections, central potential, H -atom.

6. Field quantization - Quantization of a real scalar field and complex scalar field. Quantization of the electromagnetic field, photons, interaction of an atom with radiation field, emission and absorption of radiation. Quantization of Dirac field.

Course – XII: Condensed Matter Physics I

1. Elementary crystallography: Crystal lattice & symmetry; unit cell; Bravais lattices; Miller indices; Bragg's law; Laue diffraction; reciprocal lattice; simple crystal structures x-ray diffraction; Bragg's law; atomic scattering factor; crystal structure factor, neutron diffraction; electron diffraction.

2. Crystal binding: Different types of binding; simple theory of ionic crystals; van der Wall's interaction.

3. Dielectric Properties of insulators; Static dielectric constant: complex dielectrilc constant; dielectric loss; classical theory of electric polarization; ferroelectricity.

4. Lattice vibrations: Vibrations monatomic and diatomic chains; acoustical and optical lattice vibrations in crystals; dispersion relation; anharmonic vibrations and thermal expansion.

5. Free electron Fermi gas: Classical free electron theory; its failures; Fermi-Dirac probability distribution function; periodic boundary conditions in a solid; density of states; Fermi energy-its dependence upon temperature; electronic specific heat of solid; paramagnetism of free electrons.

6. Band theory: Bloch theorem; motion of electrons in a periodic lattice; Brillouin zones for simple latttices; crystal momentum; effective mass; nearly free electron approximation; tight binding approximation; application to simple cubic lattices; ideas of Fermi surfaces; band structure of simple elements.

7. Magnetic properties of solids: Diamagnetism; paramagnetic susceptibility; behaviour of the rare earths and the iron group of metals; Hund's rules; ferromagnetism; classical theory; Weiss' theory; Heisenberg exchange energy; domain structure; elementary ideas of ferri- and anti-ferro magnetism; Neel temperature.

8. Semiconductors and their properties: Intrinsic and extrinsic semiconductors; mechanism of conduction in semiconductors; motion of hole-electron pair-carrier transport equation, Hall effect.

Superconductivity: Properties of super conductors, type I and II super conductors; super conducting magnets; Meissner effect; London's equations; electron tunneling; Josephson effect.

Course – XIII: Nuclear and Particle Physics I

1. Nuclear models and basic properties of nuclei - Shell model- experimental evidences - spin-orbit coupling; spin, paity, quadrupole moment, and magnetic moment of nuclear ground states - Schmidt lines; inadequacy / limitations of the shell model.

2. Interaction of radiation with matter - Interaction of heavy particles with matter - specific ionization - Bethe's theory - straggling. Interaction of electrons with matter - range energy relations - Bremsstrahlung: Interaction of gamma radiation with matter - photoelectric effect, Compton scattering and pair production.

3. Nuclear interactions and nuclear reactions - Ground state of deuteron; nucleon-nucleon scattering (low energy) - magnetic moment and quadrupole moment - spin dependence and charge independence of nuclear force. Compound nuclear reaction - reciprocity theorem - Breit-Wigner one-level formula resonance scattering - Ghosal' s experiment.

4. Accelerators and detectors - Cyclotron, synchrocyclotron, synchrotron, betatron - phase stability and phase oscillation. Geiger-Muller counter, bubble chamber, scintillation detector, Cerenkov detector, and semiconductor detector.

5. Nuclear decay - Alpha decay - Gamow's theory - alpha spectrum and systematics. Beta decay - Ferni's theory on beta decay - beta spectrum - selection rules - allowed and forbidden transiitions - parity violation - neutrinos. Gamma decay - multipole transition - angular momentum and parity selection rules - internal conversion - nuclear isomerism.

6. Neutron physics and basic theory of nuclear reactors - Passage of neutrons through matter; slowing down, absorption, diffusion and leakage - equation of continuity - Fermi age. Nuclear reactor - condition of criticality - critical size of infinite homogeneous reactors of different shapes.

7. Cosmic rays and elementary particles – Origin of primary cosmic rays - composition and energy spectrum, pions and muons - properties and production - Stroemer's theory - cosmic rays in atmosphere.

Different types of interaction of elementary particles classification of elementary particles, isospin and its conservation - SU(2) and SU(3) multiplets - quark model - Gellman-Okubo mass formula; Quantum chromodynamics, quark confinement, asymptotic freedom.

Course – XIV: Atomic and Molecular Physics

1. One-electron atom - Quantum states, atomic orbitals; H-atom spectrum, fine structure of H-atom, Lamb-Rutherford experiment, Lamb shift, hyperfine structure.

2. Two-electron atom - Spectral terms, exchange degeneracy, singlet and triplet structure; LS, JJ and mixed coupling schemes.

3. Many-electron atom - Independent particle model, central field approximation, Russel-Saunders coupling, alkali spectra, fine and hyperfine structure in alkali spectra.

4. Interaction with external fields - Time dependent perturbation treatment, electric dipole approximation, stimulated and spontaneous emission, absorption coefficients, selection rules, line broadening. Normal and anomalous Zeeman effect, Paschen-Back effect, Stark effect.

5. Laser - Basic requirements, population inversion and stimulated emission, three and four level lasers, N2, CO2 and He-Ne lasers. Rate equation in three level system, optical resonators, mode locking, pulse lasers. Temporal and spatial coherences, line broadening, collision and Doppler broadening. Holography.

6. Molecular orbitals - Linear combination of atomic orbitaI, H -molecular ion, H-molecule, HeitIer London theory.

7. Molecular spectra - Rotation of a diatomic molecule, rotational transition, selection rules, rotational spectra of diatomic molecules as rigid rotor and as non-rigid rotors Stark effect in molecular rotation spectra. Diatomic molecules as linear symmetric top and asymmetric top. Vibration of diatomic molecules, harmonic oscillator, anharmonicity, selection rules and spectrum, symmetry property of molecular vibration, intensity of spectral lines. Rotation-vibration spectra of diatomic molecules, PQR branching, Raman spectroscopy - pure rotational spectra and vibrational spectra. Electronic spectra' of diatomic molecules, Frank-Condon principle. Born-Oppenheimer approximation, vibrational and rotational structure.

Course– XV: Lab course III

(List of experiments should be regarded as suggestive of the standard and may not be strictly adhered to. New experiments of similar standard may be added and old experiments may be deleted whenever felt it necessary)

1. Determination of ultrasonic velocity in liquids using an ultrasonic interferometer.

2. Study of absorption lines of a substance using a spectrograph.

3. To study the spatial and temporal coherence of LASER using Michelson's Interferommeter.

4. To study the characteristics curve of G.M. counter, and (a) to study the statistical fluctuation in cosmic ray background radiation, (b) to study the decay of activity of an artificially activated source, (c) to find out the gamma counting efficiency of G.M. tubes, (d) to study the gamma absorption in lead, (e) to study the beta absorption in Aluminum and hence to determine maximum beta energy.

5. To calibrate the given condenser and to determine the values of unknown resistance and capacitance.

6. To find out the dielectric constant of a liquid using a transmission line.

7. To determine the excitation potential of a gas using Frank-Hertz tube.

8. To calibrate a Pirani gauge.

9. Determination of Curie temperature of a ferromagnetic material.

10. To study the optical absorption of a semiconductor and determination of its band gap.

11. Study of Zeeman effect.

12. Determination of e/m ratio using a magnetron.

13. Study of x-ray diffraction of a simple salt by the powder method and determination of its structure.

14. Measurement of dielectric constant of a polar liquid as a function of temperature and determination of the dipole moment.

Course – XVI: Viva , Seminar & Group Discussion

Semester IV

Course – XVII: General Relativity and Astrophysics

General Relativity: Riemannian geometry; vectors and tensors; parallel transport, integrability of parallel transport; covariant differentiation, geodesics; Riemann Christoffel curvature tensor, Bianchi identity; Ricci tensor; curvature scalar; condition of flatness; Einstein tensor.

Energy momentum tensor for dust and perfect fluid; conservation laws; principle of equivalence (PE) and general covariance; gravitational red-shift form PE; need for curved space-time to represent gravitation; heuristic derivation of Einstein's field equation; linearized equations for weak fields; gravitational waves. Schwarzschild exterior solution; integrals of motion; conditions for circular orbits; crucial tests of GR; Schwarzschild singularity; Kruskal transformation; event horizon and black hole; Kerr metric (without deduction).

Cosmological principle; open, closed and flat FRW models; Hubble constant and the deceleration parameter; Big bang model; relics of Big bang model; microwave background radiation.

Astrophysics: The Solar system; Sun - general features; sunspots; thermonuclear reactions; pp chain reaction, CNO cycle; solar neutrino problem, planets - general features.

Hydrostatic equilibrium of a Newtonian star; Lane-Emden equation; steller evolution; white dwarf, neutron star, pulsar.

Course – XVIII: Special paper I

Group – A: Condensed Matter Physics II

1. Lattice dynamics: Born-Oppenheimer approximation; phonons; photon-phonon, electron-phonon and neutron-phonon interactions; N-process and U-process; phonon spectrum; singularities in phonon spectrum; Van Hove's theorem (statement only); Debye-Waller factor; anharmonic effects; thermal expansion and thermal conductivity for determining phonon dispersion curves.

2. Ferromagnetism: Exchange interaction and Heisenberg's theory of ferromagnetism; Block's theory of free electron ferromagnetism; collective electron theory; magnons; magnon dispersion relation (for both ferro and anti-ferromagnetie substances); Block's T 3/2 law; neutron scattering by magnons; Ising model; Landau's theory of diamagnetism.

3. Magnetic resonance: Basic theory; spin-spin and spin -lattice relaxation processes; Bloch equations; steady state solutions; Bloch susceptibilities; line width; motional narrowing; nuclear magnetic resonance (NMR); Knight shift in metals; electron spin resonance (ESR); crystal field theory; ENDOR; Overhauser effect; methods for measuring relaxation times; SWR, RME, AFFMR, Mossbauer effect; Mossbauer's experiment, Mossbauer coefficient - classical and quantum theory, red shift, isomer shift, quadrupole coupling, magnetic hyperfine structure.

4. Superconductivity; Heat capacity and infra-red properties of superconductors; London equation; penetration depth; coherence length; Cooper theory; Cooper pairs; BCS theory; quasi particles; flux quantization; Grover tunneling; Josephson tunneling; AC and DC effects; SQUID.

Critical Phenomena: Order parameter; Landau theory; first & second order phase transitions; critical indices; scale invariance hypothesis; effective Hamiltonian; fluctuations of order parameter, examples of systems sharing critical behaviour.

Group – B: Nuclear and Particle Physics II

1. Two-nucleon system - Deuteron problem - ground state of deuteron with non-central force, quadrupole moment and magnetic moment. Scattering length, effective range theory for n-p and p-p scattering at low energy - saturation of density and binding energy, exchange force.

2. Nuclear models - Evidence of collective model, phenomenological collective model, rotational and vibrational states, coupling of single particle with collective motion, single particle in deformed potential- Nilsson model.

3. Nuclear interactions at high energy - Nucleon-nucleon interaction at high energy and hadron structure, nucleon-nucleon potentials, meson theory, Yukawa interaction, polarization in nucleon-nucleon scattering, scattering matrix. Probing charge distribution with electrons, form factors, deep inelastic e-p scattering.

4. Nuclear reactions - Theory of elastic and inelastic scattering, coupled channels - distorted wave Born approximation - optical model, limitations of optical model. Statistical theory of compound nucleus, resonances; theory of direct reaction.

5. Accelerators and detectors - Principle of phase stability and phase oscillation in case of synchrocyclotron and synchrotron. Betatron oscillations. Linear accelerators, Pelletrons and microtrons. Focusing of particle beam, sector focused cyclotron, alternating gradient focusing. Detectors Proportional counters, multiwire proportional counters, Drift chamber, Streamer chamber, Calorimeters.

6. Relativistic Heavy-ion Interaction: MIT Bag model of a nucleus; Quark-gluon Plasma (QGP); QGP at high-temperature; QGP at high baryon density. Hydrodynamics of QGO; Bjorken's estimation of energy density in high-energy nucleus-nucleus interaction. Signatures of QGP – qualitative discussion.

Group – C: Electronics II

1. Vacuum tube ultra high frequency and microwave oscillators :

Difficulties of using ordinary vacuum tubes in UHF range. Theory of operation of magnetron, klystron, travelling-wave tube and backward-wave oscillators.

2. Semiconductor microwave devices :

Structure and principle of operation of tunnel diode/ negative resistance oscillator; varactert diode, parametric amplifier; IMPATT diode, QWITT diode. Gunn Effect: two-valley model for bulk microwave generation; MESFET.

3. Semiconductor optoelectronic devices :

LED, APD (avalanche photodiode, p-i-n diode, semiconductor lasers, charge-couple-devices (CCD), optocoupler; Drive circuit for LED and lasers.

4. Transmission lines :

Voltage and current relations; attenuation constant and phase constant; characteristic impedance; reflection coefficient; standing-wave ratio; open and short-circuited lines and lines terminated with finite impedance; behaviour of lines of different lengths; Q of a transmission line; Transmission line measurements. Smith chart.

5. Wave guide and cavity resonator:

Theory of wave propagation between conducting parallel planes and in rectangular and cylindrical waveguides; Modes of electromagnetic radiation in a cavity: TE and TM modes, cut-off frequency, group and phase velocities; waveguide measurements. Rectangular and cylindrical cavity resonators; Q of a resonator; Horn antennas.

6. Antennas :

Directive gain; Radiated power and radiation resistance; Dipole antenna; Vertical antenna of different lengths; Arrays of antennas Loop, Yagi and other special purpose antennas.

Radio wave propagation:

Space wave propagation; atmospheric effects; the ionosphere and its layers; effect of magnetic field of the earth; reflection and refraction of sky waves by the ionosphere; skip distance and maximum usable frequency; fading; Chapman's theory of formation of ionospheric layers; measurement of ionospheric height and electron concentration; Solar activity and its effect on radio wave propagation.

Course – XIX: Special paper II

Group – A: Condensed Matter Physics III

Structure determination of solids: Crystal symmetry, Bravais lattice; transformation of crystal lattices; point groups; space groups; simple application of group theory to symmetry O,f crystals; space group determination; rotation and Weissenberg photographs; Fourier transform and its application; theory of structure analysis; Patterson synthesis and its application in structure determination; direct methods of crystal structure determination; diffraction of X-rays in presence of thermal vibrations; electron diffraction and neutron diffraction for structure determination. Advantage of neutron diffraction over X-ray diffraction, general idea of defects in crystals, colour centres; Quasi crystaJs, Nanomaterials; liquid crystals; Elementary concepts of surface crystallography, scanning, tunneling & atomic force microscopy.

Band theory of solids: Calculation of energy bands in solids; tight binding and LCAO methods; OPW method; cellular and augmented plane wave method; symmetry of energy bands; calculated energy bands; experimental study of electronic energy levels in solids; cyclotron resonance; anomalous skin effects; de Haas-van Alphen effect.

Semiconductors: Band structure of common semiconductors; effective mass theory; intrinsic and extrinsic semiconductor - statistics of electron-hole carriers and Fermi energy; dynamics of electrons ands holes; generation and recombination processes; surface recombination; Shockley-Reed mechanism of recombination; life time of carriers; Hall effect and Hall coefficient for two carrier types, origin of positive Hall coefficient for metals, modiification of Hall coefficient for velocity distribution of carriers.

Dielectric properties: Dielectric polarization; Debye's theory of dielectric relaxation, Cole-Cole plot, Onsager-Kirkwood theory, Ferroelectricity; ferroelectric crystals Barium Titannate etc. ; polarization catastrophe; LST relation in ferroelectrics.

Optical properties: Drude-Lorenz theory of metals and insulators; complex dielectric constant and its relation with optical properties of a solid; dispersion and absorption; reflection and absorption coeffiicients; Kramers-Kronig relations; quantum theory of optical transitions in a solid; direct and indirect, allowed and forbidden transitions; excitons; Frenkel and Mott-Wannier excitions.

Group – B: Nuclear and Particle Physics III

A. Relativistic kinematics - Laboratory system and C.M. system, Lorentz transformation; Mandelstam variables, invariant cross-section, phase space density.

B. Symmetries - Lie groups, Lie algebra, root and weight diagrams, Young's tableau, SU(2) and SU(3) groups. Discrete symmetries, parity, charge conjugation, and time reversal - CPT theorem. Noether's theorem and conserved currents. Gauge theories, abelian and non-abelian gauge invariance, spontaneous symmetry breaking and Higg's mechanism.

C. Quantum electrodynamics – Elements of Dirac's theory. Free field theory; scalar, spinor and vectors fields; covariant commutation relations and Feynman's propagators. Interacting field theory; covariant perturbation theory, S-matrix, Wick's theorem, cross-section and decay rates; spin sum and averaging; Feynman rules and graphs for QED. Lepton-lepton scattering; Moller scattering, Bhabha scattering, Compton scattering; electron – nucleus scattering.

Group – C: Electronics III

A. Communication principles:

Amplitude, frequency and phase modulation; Methods of modulation and demodulation; Double-sideband (DSB) suppressed carrier, single sideband (SSB) and vestigial sideband modulation; various techniques of pulse modulation and detection, PAM, PCM.

Application to T V and Radar- Basic principles of TV transmission and reception; Elements of radar, azimuth and range measurements.

B. Microwave communications :

Advantages and disadvantages of microwave transmission; propagation of microwaves, loss in free space; atmospheric effects and propagation; Fresnel zone problem, ground reflection, fading sources.

Microwave communication system - Multiplexing, repeaters, detectors, components and antennas.

C. Satellite communication :

Kepler's law and orbital satellites, geostationary satellites, station keeping; orbital patterns, look angles, orbital spacing, various satellite systems, link modules; Transmission path; Power budget calculations.

D. Fiber optic communication :

Optical fiber- An optical waveguide, total internal reflection, numerical aperture; Advantages; Manufacture of fibers and cables, splices; various kinds of losses; Dispersion.

Optical communication systems- Transmitter, receiver; Point-to-point fiber link; wavelength division multiplexing (WDM); Repeater and optical amplifier.

E. Advanced Digital Circuits :

Shift registers; asynchronous and synchronous counters, Cascade counters; (ROM), PROM and PLA, EPROM; Random-access memory (RAM) and their applications. Digital to analog and analog-converters.

F. Digital Communication ;

Advantages and disadvantages: Sampling theorem, quantization Sample and hold (S/H) circuit. Pulse code modulation (PCM), delta modulation, adaptive delta modulation; ASK, FSK,PSK, DPSK, coherent and noncoherent ASK,PSK and FSK signals; Data communication.

G. Microprocessor :

Introduction to microprocessor: Neumann's architecture, BUS structure. Intel 8085 CPU –architecture with functional blocks and ALU; Register sections.

Assembly language programming – Instruction format with simple examples, looping and time delay.

Course – XX: Lab Course IV

(List of experiments should be regarded as suggestive of the standard and may not be strictly adhered to. New experiments of similar standard may be added and old experiments may ~e deleted whenever felt it necessary)

Group – A: Condensed Matter Physics

1. Measurement of the Hall coefficient of a given sample and calculation of its carrier concentration.
2. Measurement of the energy gaps of (i) silicon and (ii) germanium.
3. Measurement of the coercive field and saturation polarization of a ferroelectric sample.
4. Measurement of the anisotropy of magnetic susceptibility of crystal by (i) Krishnan's method and (ii) Oscillation method.
5. Determination of spin-spin relaxation time of a given sample and the value of the spectroscopic splitting factor (g) by ESR method.
6. Determination of the concentration of colour centres in an alkali halides crystal.
7. Study of the characteristics of a photo-diode and calculation of its efficiency of energy conversion.

8. Determination of the value of the lattice parameter and Bravais lattice type of a cubic crystal by Debye-Scherrer method.

9. Obtaining the Laue photograph of a single crystal and drawing gnomonic projections and indexing the spots.

10. Determination of the transverse magneto-resistance coefficient of a given sample and finding the mobility of the carriers.

11. Determination of the cell dimensions of a given single crystal from rotation photograph.

Group – B: Nuclear and Particle Physics

1. To study the gamma ray spectra using a scintillator detector and a single channel analyzer.

2. To calibrate the gamma ray spectrometer, and to find out its resolution and efficiency for gamma detection.

3. Measurement of Compton scattering cross-section and photoelectric effect cross-section.

4. To study gamma absorption in Pb/Hg using gamma ray spectrometer.

5. To study the beta absorption in AI, using G.M. counter - Feather's method.

6. To study Rutherford's scattering of alpha particles.

7. To study the beta spectrum from different beta sources.

8. To study the Compton effect using scintillator.

9. To study (i) the hadronic interactions, (ii) heavy-ion interactions, (iii) pi-mu decay, and (iv) to measure charge of nuclear fragments in nuclear emulsion.

Group – C: Electronics

(List of experiments should be regarded as suggestive of the standard and may not be strictly adhered to. New experiments of similar standard may be added and old experiments may be deleted whenever felt it necessary).

1. Design and construct Butterworth First order, second order and 4th order Low pass, High pass filters. Plot the frequency response curves for these low pass filters. Determine the phase angles and the cut off frequencies.

2. Using an IC-555 construct the following circuits and study them:

(a) Astable Multivibrator (b) Schmitt Trigger (c) Sawtooth wave generator (d) Voltage Controlled Oscillator generator

3. Design and study the following properties of a positive voltage power supply using an IC 723.

(i) Variation of output voltage with input voltage.

(ii) Effect of load current on stabilized output voltage for two different line voltages.

(iii) Same as (ii) when a series pass transistor 2N3055 is connected as a current booster.

(iv) Determine the voltage stabilization ratio S_v, output resistance Ro.

4. (a). Design and study an amplitude modulator circuit using transistor and determine the percentage of modulation by (i) envelope method, (ii) trapezium method.

(b). To construct a detector circuit for AM waves and study its performance.

5. To detect frequency modulated waves using the IC phase-locked loop

6. (a) To construct and study a four bit ripple counter.

(b) To construct and study a decade counting unit.

7. Experiments on Fiber Optics:

i. Setting up Fiber Optics analog link
ii. Setting up Fiber Optics digital link
iii. Intensity modulation system using analog input
iv. Intensity modulation system using digital input
v. Frequency modulation system
vi. Pulse modulation system
vii. Propagation loss in optical fiber
viii. Bending loss in optical fiber
ix. Measurement of optical power using optical power meter(OPM)
x. Measurement of propagation loss using OPM
xi. Measurement of Numerical Aperture
xii. Setting up of FO voice link using Intensity Modulation
xiii. Setting up of FO voice link using FM
xiv. Setting up of FO voice link using PWM

8. Experiments with the 8085 microprocessor:

9. Microwave Experiments:

(a) To study the characteristics of wave propagation in a waveguide by studying standing wave pattern and hence to plot ω-β diagram.

(b) To verify relationship between guide wavelength λ and free space wavelength using a wave-guide slotted section

(c) To study the mode characteristics reflex Klystron and hence to determine mode number, transit time, electronic tuning range (ETR) and electronic tuning sensitivity (ETS).

(d) To study Gunn oscillator as a source of microwave power and hence to study (a) I-V characteristics, (b) Power frequency versus bias characteristics and (c) power-frequency characteristics.

(e) To study the properties of E-and H-plane waveguide tee junctions and to determine isolations, coupling coefficients and input VSWRs.

(f) To study isolation. Coupling coefficients and input VSWRs of an E-H tee or Magic tee.

(g) To study E-plane and H-plane radiation pattern of a pyramidal horn antenna and compute (a) beam width and (b) Directional gain of the antenna.

(h) To study the characteristics of a directional coupler.

(i) To study the operation of a ferrite circulator and hence measure (a) insertion loss, (b) isolation (c) Cross coupling (d) Input VSWR at a given frequency and study their variation with frequency.

Course – XXI: Project/ Field Studies/ Book Reviews

Semester I

Inter disciplinary Course: IDC – 1

Computational Methods and Programming –I Programming: Instructions to a computer; machine language; high level language; different programming languages; Interpreter and compiler; overview of FORTRAN language; input-output statements; mathematical assignment statements; control statements; function and subroutine subprogrammes; subscripted variables; string variables; files.

Liquid Crystals:

Types of liquid crystals; Identification of liquid crystalline phases; molecular theories of nematic liquid crystals; Molecular theories of Smectic A liquid crystals, Landau-de Gennes theory of phase transition in liquid crystals; X-ray diffraction studies of liquid crystals, Liquid crystal displays.

Semester II

Inter disciplinary Course: IDC – 2

Computational Methods and Programming –II Interpolation: Newton's formulas; Lagrange's interpolation; inverse interpolation.

Numerical differentiation and integration: Numerical differentiation; numerical integration - Simpson's, Weddle's and trapezoidal rules; Gauss' quadrature formula; accuracy of quadrature formulas.

Fundamental Electronics:

Basic small signal amplifiers: Classification of amplifiers, BJTIFET amplifier circuits, model and generalised amplifier circuits, Bootstrapped and Darlington amplifier circuit. Audio power amplifiers. Audio power amplifier requirements, Class A, Class B and Class C power amplifiers, Push pull and tuned power amplifiers. Cascade amplifiers, Diffference amplifiers, Multistage R-C coupled amplifiers. Noise in electronic circuits

Block diagram of a typical OP-AMP circuit: Open-loop configuration. Practical OP AMP: Input offset voltage and current, input bias current, total output offset voltage, CMRR and frequency response Inverting and non-inverting amplifiers. OP AMP with negative feedback - voltage series feedback. Effect of feedback on closed loop gain, input resistance, output resistance, bandwidth, offset voltage and current, voltage follower.