Syllabus

of

M. Sc. in Physics Course

(Effective from the Academic Session 2011-2012)

Department of Physics

Institute of Science

Visva-Bharati

APPROVED BY THE BOARD OF STUDIES, DEPARTMENT OF PHYSICS

ON 30th APRIL, 2011.

CONTENTS:

1. **SEMESTER-WISE DISTRIBUTION OF COURSES**
2. **SYLLABUS OF CORE COURSES OF PHYSICS**
3. **SYLLABUS OF ELECTIVE COURSES OF PHYSICS**

Syllabus of M. Sc. in Physics Course
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Semester-wise Distribution of Courses
Full marks-1200

(20% of Full Marks for each course will be the Internal Assessment Marks for that course)

Semester-I, Total Marks-300

	Course No.	Name of the course	Marks	Credit point
1.	MPC-11	Mathematical Methods-I	50	4
2.	MPC-12	Classical Mechanics-I	50	4
3.	MPC-13	Condensed Matter Physics	50	4
4.	MPC-14	Quantum Mechanics-I	50	4
5.	MPC-15	Electronics	50	4
6.	MPC-16	Electronics Practical-I	50	4

Semester-II, Total Marks-300

	Course No.	Name of the course	Marks	Credit point
7.	MPC-21	Mathematical Methods-II	50	4
8.	MPC-22	Classical Mechanics-II	50	4
9.	MPC-23	Classical Electrodynamics & Plasma Physics-I	50	4
10.	MPC-24	Quantum Mechanics-II	50	4
11.	MPC-25	Nuclear Physics	50	4
12.	MPC-26	Electronics Practical-II	50	4

Semester-III, Total Marks-300

	Course No.	Name of the course	Marks	Credit point
13.	MPC-31	Statistical Mechanics	50	4
14.	MPC-32	Classical Electrodynamics & Plasma Physics-II	50	4
15.	MPC-33	Computer Applications in Physics-I	50	4
16.	MPC-34	General Practical-I	50	4
17.	MPC-351	Electronics.-I	50	4
	MPC-352	Condensed Matter Physics–I		
	MPC-353	Quantum Electronics -I		
	MPC-354	Nuclear Physics –I		
	MPC-355	Quantum Field Theory		
18.	MPE-361	Elective Course	50	4
	MPE-362	,,		
	MPE-363	,,		
	MPE-364	,,		
	MPE-365	,,		

Semester-IV, Total Marks-300

	Course No.	Name of the course	Marks	Credit point
19.	MPC-41	Atomic and Molecular Physics	50	4
20.	MPC-42	Dissertation/Project #	50	4
21.	MPC-43	Computer Applications in Physics-II	50	4
22.	MPC-44	General Practical-II	50	4
23.	MPC-451	Electronics-II (Practical)	50	4
	MPC-452	Condensed Matter Phys.-II (Practical)	50	4
	MPC-453	Quantum Electronics-II (Practical)	50	4
	MPC-454	Nuclear Physics -II (Practical)	50	4
	MPC-455	Particle Physics-I	50	4
	MPC-456	Astrophysics	50	4
	MPC-457	Laser Physics	50	4
24.	MPC-461	Electronics -III	50	4
	MPC-462	Condensed Matter Phys.-III	50	4
	MPC-463	Quantum Electronics -III	50	4
	MPC-464	Nuclear Physics -III	50	4
	MPC-465	Particle Physics -II	50	4
	MPC-466	Cosmology	50	4

This course may be started in Semester-III, but will be evaluated at the end of Semester-IV

At the end of Semester-II, students have to select one out of the following Modules of Courses:-

Module 1: Electronics: MPC-351, MPC-451, MPC-461

Module 2: Condensed Matter Physics: MPC-352, MPC-452, MPC-462

***Module 3: Quantum Electronics: MPC-353, MPC-453, MPC-463**

Module 4: Quantum Electronics: MPC-353, MPC-457, MPC-463

Module 5: Nuclear Physics : MPC-354, MPC-454, MPC-464

Module 6: Particle Physics: MPC-355, MPC-455, MPC-465

Module 7: Astrophysics: MPC-355, MPC-456, MPC-466

* This module will be offered in near future in place of Module 4, and then the course MPC-457 (Laser Physics) will be offered as one elective course (MPE).

IMPORTANT POINTS:

- **AT THE END OF THE SEMESTER II, SEVERAL ELECTIVE COURSES FOR SEMESTER III WILL BE OFFERRED FOR THE STUDENTS CHOICE. THE NUMBER OF ELECTIVE COURSES EVERY YEAR WILL BE DECIDED BY THE DEPARTMENT. OUT OF THE OFFERRED COURSES, STUDENTS HAVE TO SELECT ONE COURSE FOR SEMESTER-III. HOWEVER, THE FINAL DECISION IN THIS CASE WILL BE MADE BY A COMMITTEE WITH H.O.D. AS THE CONVENER.**
- **20% OF THE FULL MARKS PER COURSE WILL BE THE INTERNAL ASSESSMENT MARKS.**
- **INTERNAL ASSESSMENT MARKS SHOULD BE BASED ON ATLEAST ONE WRITTEN TEST AND CONTINUOUS ASSESSMENT, TUTORIALS, ASSIGNMENTS, ETC.**

Syllabus

of

Core Courses for

M. Sc. in Physics

Semester-I
Course No. MPC-11
(Credit-4)
Mathematical Method-I

Lectures: 50
Full marks: 50

1. **Complex Variable and Functions**: Function of complex variable, Cauchy's theorem, Cauchy's integral formula, contour integration, branch points, branch cuts, singular points, Taylor and Laurent expansion, Schwartz reflection principle, residue theorem for evaluation of definite integrals, analytic continuation, Gamma function. (20)

2. **Complex Mapping:** Transformation or mapping, Complex mapping functions, some general transformations, translation, rotation, stretching, inversion, the liner transformation, Conformal mapping. (10)

3. **Second Order Linear Differential equations with variable coefficients**: Power series solution method; Legendre polynomial, Hermite polynomial, Bessel's polynomial, Lagurre polynomial, Hypergeometric and Confluent Hypergeometric functions; Green's function method. (20)

References:

1. Schaum's outline of theory and problems of complex variables with an introduction to conformal mapping and its applications, Murray R. Spiegel, McGraw-Hill.

2. Complex Analysis – L. V. Ahlfors
3. Complex Variables and Applications: R V Churchill and J W Brown, (McGraw-Hill)
4. Mathematical methods for Physicists: Arfken and Weber. Elsevier
5. Mathematical methods of physics – J Mathews and R I Walker (Pearson)
6. Advanced Engineering Mathematics -- Erwin Kreyszig, Wiley Eastern University Edition.
7. Mathematical Methods for Physicists an Engineers – K. F. Reily, M. P. Hobson and S. J. Bence.
8. Mathematics for Physicists - M L Boas

Semester-I

Course No. MPC-12
(Credit-4)
Classical Mechanics-I
Lectures: 50
Full marks: 50

1. **Elements of Lagrangian and Hamiltonian formulations of mechanics:** Differential and integral approaches, Jacobi integral, gauge invariance, dissipative systems, equivalent and inequivalent Lagrangians. (8)
2. **Motion in a central force field:**
   Equivalent one-body problem, General features of the motion, classification of orbits, Planetary motion, the Kepler problem, Perturbation of orbits. (8)
3. **Decay and Scattering processes**:
   Kinematics of decay of a particle; Elastic & Inelastic scattering, Transformation between C- and L- frames; Scattering cross-sections, Rutherford scattering. (8)
4. **Dynamics of Rigid Body Motion:**
   Fixed and moving coordinate systems of a rigid body, the Eulerian angles, Angular momentum and kinetic energy of a rigid body, the Inertia tensor, Euler's equations of motion, motion of a heavy symmetric top; Accelerated coordinate systems: Coriolis force. (10)
5. **Theory of small oscillations:**
   General case of coupled oscillations, eigen-modes and eigen-frequencies, Normal coordinates; small oscillations of particles on strings, Forced vibrations and dissipative forces for many-dimensional systems. (8)
6. **Canonical Transformations and Hamilton-Jacobi theory:** Canonical Transformations, Conditions for transformations to be canonical, examples of canonical transformations; Poisson and Lagrange brackets and canonical transformations; infinitesimal contact transformations. (8)

References:

1. Classical Mechanics - H. Goldstein.
2. Mechanics – L. D. Landau and E.M. Lifshitz
3. Foundation of theoretical Mechanics –I – R.M. Santilli
4. Applications of Lie Groups to differential equations – P.J. Olver
5. Classical Dynamics – A modern perspective – E.C.G. Sudarshan and N. Mukunda
6. Gravitation and Cosmology - S. Weinberg
7. General relativity and Cosmology – J.V. Narlikar

Semester-I
Course No. MPC-13
(Credit-4)
Condensed Matter Physics
Lectures: 50
Full marks: 50

1. **Crystal Structure:**
   Periodic arrays of atoms, Fundamental types of lattices, Index system of crystal planes, Packing of crystals, Simple crystal structures (e.g., sodium chloride, cesium chloride, diamond, zinc sulphide). Diffraction of waves by crystal – Braggs law, Fourier analysis of scattered wave amplitude, reciprocal lattice vectors, diffraction conditions, Laue equation, Brillouin zones, Elastic scattering. (8)
2. **Phonons: Crystal Vibrations & Thermal Properties:**
   Vibrations of crystals with monoatomic basis, dispersion relation, group velocity, Vibrations of crystals with diatomic basis, dispersion relation, acoustical and optical phonon modes, Quantization of elastic waves, phonon momentum, inelastic scattering of phonons. Brief discussion : Phonon heat capacity, Planck distribution, Density of states- Einstein and Debye model, Debye T^3 law. (8)
3. **Electronic properties of solids:**
   Free electron gas in three dimensions, Density of states and heat capacity of metals, Boltzmann transport equation, electrical conductivity of metals, motion of electron in magnetic field – Hall effect. (5)
4. **Energy Bands:**
   Nearly free electron model, energy gap, Bloch functions, Kronig-Penny model, electrons in a periodic potential, Bloch theorem, solution near zone boundary, metals and insulators; Fermi surface, Tight binding model, de Haas van Alfen effect. (8)
5. **Semiconductors:**
   Intrinsic and extrinsic semiconductors, mobility, carrier concentration, position of Fermi level, p-n junction, photo-voltaic effect.. (3)
6. **Magnetism:**
   Diamagnetism: Langevin's classical theory, quantum theory. Paramagnetism: Langevin's classical theory, Weiss molecular field theory and quantum theory. Ferromagnetism: Weiss classical theory, quantum theory, origin of intermolecular field and exchange interaction, Curie temperature, domain. Antiferromagnetism: Molecular field treatment and two sublattice model. Ferrimagnetism: Neel's theory, Neel temperature. (8)
7. **Superconductivity:**
   Occurrence of superconductivity - Experimental survey, Meissner effect, Type 1 and Type 2 superconductors, London equation, penetration depth, BCS theory (basic idea), flux quantization, Josephson tunneling, ac and dc Josephson effect. (7)
8. **Ferroelectrics**:
   General properties of ferroelectric materials and classification, Dipole theory, ionic displacement behavior of $BaTiO_3$ and theory of spontaneous polarization. Curie law. (3)

References:

1. Introduction to solid state physics – C. Kittel
2. Solid state physics – Ascroft & Mermin
3. Introduction to solids – Azaroff
4. Principles of theory of solids – J.M. Ziman
5. Elementary solid state physics – Omar
6. Solid state physics – S.O. Pillai

Semester-I

Course No. MPC-14
(Credit-4)
Quantum Mechanics-I

Lectures: 50
Full marks: 50

1. **Introduction:** Wave particle duality, de Broglie wavelength, wave packets, evolution of wave packet; phase and group velocity, dispersion relation, Heisenberg's uncertainty relation (4)
2. **Postulates of Quantum Mechanics:** Wave function, Operators, linear and hermitian operators, observables, measurement and eigenvalue equations, Schrodinger equation, superposition and collapse of wave function, probability and current densities; the continuity equation, normalisation of wave function, box normalization; Ehrenfest theorem, expectation values, Admissibility conditions on wave functions. (8)
3. **Exactly Solvable Problems:**
   One Dimensional Problems: Stationary states, time-independent Schrodinger equations, infinite potential barrier, square potential barrier, square potential well, simple harmonic Oscillator.
   Higher Dimensional Problems: N-particle system in three dimensions, particle in a Box and degeneracy of levels; the two particles system; the rigid rotator, isotropic and anisotropic harmonic oscillators. (10)
4. **Mathematical Formulation:** Matrices, vectors, Hilbert space, Schwarz inequality, state vectors and Dirac notation, discrete and continuous basis, completeness and closure relations, orthonormalizability of eigen kets; operators and observables, commutator relations, Unitary operators; postulates of quantum mechanics, uncertainty relation, coordinate and momentum representations; evolution of state vector, Schrodinger, Heisenberg and interaction picture; creation and destruction operators and the simple harmonic oscillator problem. (12)
5. **Motion in a Spherically Symmetric Potential:** Orbital angular momentum, Rotation generators, ladder operators, commutators, expression in polar coordinates, eigenvalues and eigenfunctions of L^2 and L_z, spherical harmonics; the radial equation; The hydrogen atom. (7)
6. **Symmetries in Quantum Mechanics:** Translations, rotations, parity, time reversal, invariance and conservation laws. (6)
7. Introduction to spins, spin operators and spin eigenstates. (3)

Reference:

1) Quantum Mechanics – D J Griffiths (Pearson)
2) Principles of Quantum Mechanics – R Shankar (Springer)
3) Quantum Mechanics – Libboff
4) Quantum Mechanics -- Jataily
5) A textbook of Quantum mechanics – Mathews and Venkatesan (Tata-McGrawHill)
6) Quantum Mechanics (Vols 1 and 2) – A. Messiah
7) Quantum Mechanics - L.I. Schiff
8) Quantum Mechanics - E. Merzbacher
9) Quantum Physics – S. Gasiorowicz
10) Modern Quantum Mechanics – J.J. Sakurai
11) Quantum Mechanics 1& 2 – Cohen-Tannoudji et.al

Semester-I
Course No. MPC-15
(Credit-4)
Electronics
Lectures: 50

Full marks: 50

1. **Filter:** Constant -K filters - High-pass and low-pass filters-Calculation of attenuation constant and phase shift constant-design of HPE and LPE – shortcomings of constant-K filters. (5)
2. **Transmission line:** Derivation of Telegraphers equations – solutions of current and voltage on the transmission line- calculation of input impedence of the line – fault location on the transmission line. (6)
3. **Elements of communication receiver:** Outlines of Phase-Locked loop – basic operation – basic description of phase detector, VCO, and low-pass filter – FM signal demodulation. (6)
4. **Fibre-Optic communication:** The fields in the core and cladding of the step-index fiber – characteristic equation – mode characterization, single mode optical fiber – delay distortion in single-mode fiber – dispersion in step-index fiber. (6)
5. **Microwave solid state devices:** Gunn diode, RWH mechanism, modes of operation, of Gunn diode, IMPATT diode, Read diode, calculation of avalanche sone and drift zone impedance, performance limitations of IMPATT diode oscillators. (7)
6. **Digital modulation:** ASK, FSK, PSK (2)
7. **Digital electronics:** Binary adder, half adder and full adder, CLA adder, 2's complement adder-subtractor, magnitude comparator, Karnaugh mapping, Flipflop, shift register, counter, basic principles of A/D and D/A converters. (7)
8. **Radar:** Basic radar system, radar range equation, CW radar, moving target indicator, (MTI) radar, frequency modulation radar. (5)
9. **Photonic devices:** LED (high frequency limit, effect of surface and indirect recombination current, operation) – diode laser – optical gain and threshold current for lasing FP cavity. (6)

References:

1. Networks, lines and fields - J.D. Ryder
2. Telecommunications - Fraser
3. Microelectronics - Millman & Grabel
4. Physics of semiconductor devices - S.M. Sze
5. Principles of communication systems –Taub and Schilling
6. Introduction to digital Principles - Malvino & Leach
7. Handbook of electronics – F.E. Terman
8. Optical Electronics – A Ghatak and K Thyagarajan
9. Advanced Electronics – T. P. Chattopadhyay, CBS Publishers, New Delhi.

Semester-I
Course No. MPC-16
(Credit-4)
Electronics Practical-I

Full marks: 50

1. Applications of OP-Amp as

    a) Inverting amplifier
    b) Active low pass filter
    c) Integrator
    d) Active High Pass filter
    e) Differentiator

2. Measurement of open and short circuit impedances/resistances of a ladder network and determine the equivalent T- and π-networks
3. Study the input-output characteristics of an optical trans-receiver
4. Design of an MS-JK flip-flop using NAND gates
5. Programming using Microprocessor

    a) Multibyte addition
    b) Single byte multiplication

Reference:

1. Electronic Instrumentation - Cooper and Helprey
2. Electronic Instrumentation - M.H. Joanes

NEW EXPERIMENTS MAY BE ADDED IN PHASES

Semester-II
Course No. MPC-21
(Credit-4)
Mathematical Methods-II

Lectures: 50
Full marks: 50

1. **Integral Transforms:**

   Fourier transforms (FT), Applications, Momentum representations. Laplace's transforms (LT), Inverse Laplace's transforms, Convolution of Laplace and Fourier transforms. Applications, Use of LT and FT to solve differential equations. (16)

2. **Integral Equations**: Conversion of a differential equation into an integral equation. Fredholm and Volterra equations, Degenerate kernels, Neumann series, Abel's integral equation. (16)

3. **Elements of Group theory:** Groups, Sub-groups, Classes, Cosets, Conjugate subgroups, Invariant sub-groups, Factor group, Homomorphism and Isomorphism, permutation group, Cayley's theorem, Direct products.
   Group representation, reducible and irreducible representations, Character of a representation, Schur's Lemma, Continuous groups: O(2) and O(3), rotation in two and three dimensions, generators of rotation group angular momentum, representation of O(3) and the spherical harmonics, SU(2) and spin, solving quantum Coulomb and/or the oscillator problem, normal mode calculations (18)

References:

1. Mathematical Methods for Physicists - G.B. Arfken.
2. Advanced Engineering Mathematics – E. Kreyszig
3. Mathematical methods of Physics - Mathews and Walker
4. Mathematical Methods for Physicists an Engineers – K. F. Reily, M. P. Hobson and S. J. Bence
5. Special Functions – E. D. Rainville
6. Mathematics for Physicists - M L Boas
7. Group theory & its application to Physical Sciences - M. Hammermesh
8. Group theory for Physicists - A.W. Joshi.

Semester-II

Course No. MPC-22

(Credit-4)

Classical Mechanics-II

Lectures: 50

Full marks: 50

1. **Hamilton-Jacobi theory:**
   Hamilton-Jacobi equation, Method of separation of variables, Action-angle variables, Degeneracy of motion and the Kepler problem, Canonical perturbation theory: the anharmonic oscillator. (10)
2. **Continuous systems and Classical fields:**
   The transition from a discrete to a continuous system, the Lagrangian and Hamiltonian formalisms, Conservation laws, Description of classical fields, the electromagnetic field, Interaction of field with matter. (10)
3. **Relativistic Classical Mechanics:**
   Brief review of Special theory of Relativity (Lorentz transformation, Force, Energy and momentum in Relativity, Four-dimensional formulation). Decay of particles and relativistic elastic scattering, the Lagrangian and Hamiltonian of a relativistic particle; Motion of a relativistic charged particle in presence of an electromagnetic field. (8)
4. **The General Theory of Relativity:**
   History of non-Euclidean geometry, Inner properties of curved surfaces, Curvature determined from distances, the Metric, measurements of the ratio of gravitational and inertial mass, Newtonian theory of gravitation, Anomalous precession of perihelion of mercury, Mach's principle, Relativity restored by Einstein, the principle of Equivalence, Gravitation and metric tensor. (Tensor Analysis: Review of algebra, tensor densities, transformation of the Affine connection, Covariant differentiation along a curve, definition of curvature tensor, gravitation versus curvilinear coordinates. (12)
5. **Einstein's Field Equations:**
   Derivation of the field equations: Vanishing of the Ricci tensor (Schwarz-Schield matrix) in vacuum, the cosmological constant, Particle and Photon dynamics, Precession of perihelia, Evaluation of FRW parameters, some notions of gravitational radiations, Introduction to standard cosmological models. (10)

References:

1. Classical Mechanics - H. Goldstein.
2. Mechanics – L. D. Landau and E.M. Lifshitz
3. Foundation of theoretical Mechanics –I – R.M. Santilli
4. Applications of Lie Groups to differential equations – P.J. Olver
5. Classical Dynamics – A modern perspective – E.C.G. Sudarshan and N. Mukunda
6. Gravitation and Cosmology - S. Weinberg
7. General relativity and Cosmology – J.V. Narlikar

Semester-II

Course No. MPC-23

(Credit-4)

Classical Electrodynamics and Plasma Physics-I

Lectures: 50

Full marks: 50

1. **Electrostatics:**
   Poisson and Laplace's equations; Formal solution of boundary value problems: Green's functions; Method of images; Multipole expansion of scalar potential; Macroscopic electrostatics ; Molecular polarizability; Boundary value problems with dielectrics. (10)
2. **Magneto-statics:**
   Biot-Savart law; Ampere's law - vectors potential; Magnetic field of a localized current distribution ; Macroscopic equations; Boundary conditions of **B** & **H**. (10)
3. **Time Varying Fields:**
   Maxwell's equations; vector and scalar potentials; Gauge transformations; Lorentz and Coulomb gauge; Poynting theorem; Conservation laws; Green's function for time dependent wave equation. (15)
4. **Plane Electromagnetic Waves:**
   Plane waves in a non-conducting medium; Linear and circular polarization; Superposition of waves; Group velocity; Kramers-Kronig dispersion relation; Reflection and refraction of electromagnetic waves; Waves in a conducting medium; resonant cavities and wave guides. (15)

References:

1. Classical Eletrodynamics - J.D. Jacksson
2. Classical Electricity and Magnetism – W.K.H. Panofsky and M. Phillips
3. Classical Electrodynamics – H. Alfven
4. Principles of Plasma Physics – N.A. Krall and A.W. Trivelpiece

Semester-II
Course No. MPC-24
(Credit-4)
Quantum Mechanics-II

Lectures: 50
Full marks: 50

1) **Theory of Angular Momentum:** Finite and infinitesimal rotations, matrix representations of Jx, Jy and Jz; coupling of two angular momenta, Clebsch-Gordon (CG) coefficients. (6)
2) **Identical Particles**: the principle of indistinguishability, symmetric and antisymmetric wave functions, the exclusion principle, connection with statistics, Slater determinant. (5)
3) **Approximation Methods**: WKB approximation and application to potential barrier (alpha decay), harmonic oscillator problems; the variational method and application to hydrogen and helium atoms. (6)
4) **Time independent perturbation theory:** Introduction, nondegenerate and degenerate cases, anharmonic oscillator with X^3 and X^4 terms, Zeeman effect, Stark effect; spin-orbit coupling and alkali atoms; singlet and triplet states of helium atom; hydrogen molecule, (6)
5) **Time Dependent Perturbation Theory:** Transition rates, harmonic perturbation, Fermi's golden rule, electric dipole approximation, absorption cross-section, spontaneous and stimulated emission of radiation, Einstein's relations; derivation of Born amplitude. (6)

6) **Scattering Theory:** The general formalism (Lab and CM frames, cross sections); partial wave analysis and phase-shifts, optical theorem, simple applications (Scattering by a rigid sphere); integral equation of scattering, Green's function, Born approximation, Coulomb scattering, Yukawa potential; spherical potential, effective range and scattering length (S-wave only). (8)

7) **Relativistic Wave Equations:** Klein-Gordon equation, continuity equation; Dirac equation, algebra of Dirac matrices, plane wave solutions, prediction of antiparticles Pauli equation, magnetic moment of the electron , covariant form, positiveness of probability density, spin of electron, Pauli spin matrices, parity, charge conjugation, time reversal operation. (10)

8) **Interpretational problems:** Double slit experiment, Born's interpretation of wave function, Schrodinger's cat experiment, Copenhagen and Statistical interpretation, Hidden variable, Bell's inequality, EPR paradox. (3)

Reference

1. All the books referred for course of Quantum mechanics I (no. MPC-14)
2. Feynmann lectures of Physics Vol III
3. A first book of Quantum Field theory – A Lahiri and P B Pal (Narosa)
4. Quantum Field Theory – L H Ryder (CUP)
5. Quantum mechanics – D Home
6. The Quantum Revolution Vol I and Vol III – G Venkataraman (University Press)
7. Quantum Mechanics: A modern development: L E Ballentine (World Scientific)

Semester-II
Course No. MPC-25
(Credit-4)
Nuclear Physics
Lectures: 50
Full marks: 50

1. **Introduction to Particle Physics:** Types of interaction between elementary particles, Hadrons and leptons, Symmetry and conservation laws, Elementary ideas of CP and CPT invariance, classification of hadrons, Lie algebra, SU(2) -SU(3) multiplets, Quark model, Gellmann-Okubo mass formula for octet and decuplet hadrons, charm, bottom and top quarks, Gellman – Nishijima formula, Unification of forces. (8)

2. **Tools of Nuclear physics:** Passage of radiation through matter, detection and measurement of nuclear radiation, particle accelerators. (3)
3. **General properties of nuclei:** Constituents of the nucleus, nuclear charge, mass and binding energy, nuclear radius, spin, parity and statistics, Coulomb energy of mirror nuclei, nuclear size from electron scattering experiments, magnetic dipole moment and electric quadrupole moment. (7)
4. **Two-body problems:** Characteristics of nuclear forces, tensor forces and exchange forces, nucleon-nucleon potential, ground state of the deuteron, excited state of the deuteron. Two-body scattering: Kinematics, cross-sections, low energy neutron-proton scattering, partial wave analysis-phase shift, singlet and triplet scattering, effective range theory, coherent scattering of neutrons by Ortho- and Para-hydrogen, low energy proton- proton scattering, charge independence and charge symmetry of nuclear forces, Isospin formalism, Yukawa interaction. (8)
5. **Nuclear Decay:**
   (a) Alpha decay - Systematics of alpha decay, Barrier- penetration, Gamow's theory of alpha decay, Geiger-Nuttal law, fine structure of alpha spectra.
   (b) Beta decay - $\beta+$ and $\beta-$ emissions and electron capture, Neutrino and antineutrino, Fermi's theory of beta decay, Kurie plots, Comparative half-life, allowed and forbidden transitions, selection rules in beta decay, Non-conservation of parity in beta decay.
   (c) Gamma decay - Gamma ray spectra, multipole moments, transition probabilities, selection rules, nuclear isormerism, internal conversion, pair production, Mossbauer effects. (8)
6. **Nuclear models:** Fermi gas model, Liquid drop model and nuclear fission, Bethe-Weizsacker semi-· empirical mass formula, stability of nuclei, Nuclear shell model (single-particle), magic numbers, magnetic moments and Schmidt lines, Collective model of Bohr and Mottelson. (8)
7. **Nuclear reactions :** Nuclear reaction kinematics, Q-value equation, threshold energy and cross-section of nuclear reactions, partial wave analysis of reaction cross-sections, formation and break up, statistical theory of the compound nucleus, scattering matrix, reciprocity theorem, resonance scattering & reactions, Breit-Wigner formula, direct reactions, optical model, Pre-equilibrium reactions, Heavy ion reactions. (8)

Reference:

1. Nuclear Physics – R.R. Roy and B.P. Nigam (New Age International)
2. Introductory Nuclear Physics – Kenneth S. Krane (Wiley)
3. Atomic and Nuclear Physics (Vol.-2) – S.N. Ghoshal (S. Chand group)
4. Introduction to Nuclear Physics – H.A. Enge (Addison Wesley)
5. Nuclear Physics – I. Kaplan (Narosa Publications)
6. Introductory Nuclear Theory – L.R.B Elton (Sir Isaac Pitman & sons)
7. Elementary Nuclear Theory – H.A. Bethe and P. Morrison (Dover Publications)
8. Nuclear Physics – E. Fermi (University of Chicago press)
9. Nuclei and Particles – E. Segre (W.A. Benjamin)
10. Theoretical Nuclear Physics – J.M. Blatt and V.F. Weisskopf (Dover Publications)
11. Physics of the Nucleus – M.A. Preston (Addison-Wesley Longman)
12. Techniques for nuclear & particle physics experiments – W. R. Leo (John Wiley & Sons Ltd.)

Semester-II
Course No. MPC-26
(Credit-4)
Electronics Practical-II
Full marks: 50

1. Applications of OP-Amp as

   i. Schmitt Trigger
   ii. Astable multivibrator
   iii. Notch filter
   iv. Phase shift Oscillator

2. Generation of square wave using 555 Timer
3. Study of Phase locked loop-FM signal demodulation characteristics
4. Design of a 8-states asynchronous counter using flip flops
5. Design of a DAC using OP-AMP
6. Programming using Microprocessor

   i. Power of a number
   ii. Square root of a number
   iii. Generation of square wave

Reference:

1. Electronic Instrumentation - Cooper and Helprey
2. Electronic Instrumentation - M.H. Joanes

(NEW EXPERIMENTS MAY BE ADDED IN PHASES)

Semester-III

Course No. MPC-31
(Credit-4)
Statistical Mechanics

Lectures: 50
Full marks: 50

1. **Basic Concept:** Random walk and statistical basis of thermodynamics; phase space and ensembles; Liouville's theorem. (3)
2. **The microcanonical ensemble:** Statistical interpretation of temperature and entropy; the equipartition and virial theorem; classical ideal gas; Gibbs paradox; Sackur-Tetrode equation. (4)
3. **The canonical ensemble:** 'l'he equilibriurn between a system and a heat reservoir; partition function; Energy fluctuations in canonical ensemble; Applications; Negative temperature. (6)
4. **The grand canonical ensemble:** The equilibrium between a system and a heat reservoir; Density and energy fluctuations in the grand canonical ensemble; critical opalescence; Applications. (6)
5. **Quantum statistical mechanics:** Density matrix; Density matrix for different ensembles, Applications; Bose-Einstein and Fermi-Dirac distributions, Statistics of the occpation numbers. (5)
6. **Ideal Bose System:** Thermodynamic behavior of an ideal Bose gas; Bose-Einstein condensation; Liquid helium; Bose condensation in gases, Phonons. (5)
7. **Thermodynamic behavior of an ideal Fermi gas:** A degenerate electron gas; white dwarf and Chandrasekhar limit, Magnetic behavior of an ideal Fermi gas. (5)
8. **Chemical reaction:** The condition for chemical equilibrium; the law of mass action; Ionization equilibrium; Saha ionization formula. (4)
9. **Imperfect gases:** Cluster expansion for classical gas; Calculation of partition function for low densities; Equation of state and virial coefficients; The Van der Waal's equation. (5)
10. **Phase transitions and Critical Phenomena:** Qualitative description and classification of phase transitions; Ising model and lattice gas; critical exponents; order parameter, correlation function and fluctuation dissipation theorem; scaling hypothesis and scale invariance. (6)

References:

1. Statistical Mechanies - R.K. Patharia
2. Statistical Mechanics - K. Huang
3. Fundamentals of statistical and thermal physics – Reif
4. Statistical Physics (III) - Landau and Lifshitz
5. Statistical Mechanics and Properties of matter – E.S.R Gopal
6. Statistical Mechanics - B.K. Agarwal and Melvin Eisner

Semester-III
Course No. MPC-32
(Credit-4)
Classical Electrodynamics and Plasma Physics-II

Lectures: 50

Full marks: 50

1. **Special Theory of Relativity:** Covariant formulations of electrodynamics; Electromagnetic field tensors; Energy-momentum tensor; Simple examples of relativistic particle kinematics and dynamics. (10)
2. **Radiation Theory:** Fields and radiation of a localized oscillating source; Dipole and quadrupole radiations; Radiation by moving charges; Lienard-Wiechert potentials; Larmor's formula; Synchotron radiation; Thompson and Rayleigh scattering; Cherenkov radiation; Bremsstrahlung. (25)
3. **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. (5)
4. **Plasma Physics:** Basic concepts, Magneto hydrodynamic (MHD) equations, Magnetic diffusion, viscosity and pressure, magneto hydrodynamic flow, pinch effect and its dynamic model, instabilities, MHD waves, high frequency plasma oscillations, short wavelength limit, Debye screening distance. (10)

References:

1. Classical Eletrodynamics - J.D. Jacksson
2. Classical Electricity and Magnetism – W.K.H. Panofsky and M. Phillips
3. Cosmical Electrodynamics – H. Alfven
4. Principles of Plasma Physics – N.A. Krall and A.W. Trivelpiece

Semester-III

Course No. MPC-33

(Credit-4)

Computer Application in Physics - I

Lecture: 50

Full marks: 50

1. Brief introduction to UNIX and LINUX. (2)
2. Brief review of C. (8)
3. Introduction to C++. (30)
4. Interactive Web-based material preparation: (5)
    1. HTML forms.
    2. CGI program in C++ - simple examples.
5. Introduction to $\LaTeX$: (3)
    1. Formatting and layout.
    2. Mathematical formatting.
    3. References, citations and bibliography.
    4. Elements of RevTEX.
6. Graphical data presentation using 'Gnuplot'. (2)
    1. Multiplot for insets and joined graphs.
    2. Interfacing with $\LaTeX$ for symbols and equations.
    3. Postscript output and inclusion in $\LaTeX$ documents.

References:

1) Teach Yourself **C**$^{++}$ - Herbert Schilds
2) **C**$^{++}$, The Complete Reference - Herbert Schilds
3) $\LaTeX$, Gnuplot – online tutorials
4) Sams Teach yourself HTML in 24 Hour – Dick Oliver.

Semester-III
Course No. MPC-34
(Credit-4)
General Practical -I

Full marks: 50

1. Use of G.M. Counter:
   (a) To study β-ray absorption in matter.
   (b) To measure the counting efficiency for the β-ray.
   (c) To study the statistics of Nuclear Counting.
2. Use of a scintillation detector to study the energy spectra of gamma rays (single channel gamma spectrometry).
3. Determination of Lande g-factor using an electron spin resonance (E.S.R.) spectrometer.
4. Determination of mass susceptibility of a given paramagnetic and diamagnetic sample.
5. Determination of Hall coefficient of the given sample.
6. Determination of various optical constants (band gap, absorption coefficient, refractive index, etc.) of a semiconductor material.
7. Ultrasonic grating.

(NEW EXPERIMENTS MAY BE ADDED IN PHASES)

Semester-III
Course No. MPC-351
(Credit-4)
Electronics -I

Lectures: 50
Full marks: 50

1. **Discrete and integrated digital circuits**
   Logic family - DTL, TTL, ECL, CMOS.
   Digital IC-Multiplexer, Demultiplexer, Encoder, Decoder, Arithmetic circuits, Registers, Counters, A/D converter and D/A converter.
   Memories-Semiconductor memories - ROM, RAM, PROM, EPROM, CCD.
   Fundamentals of Magnetic memories and Optical memories. (15)

2. **Discrete and integrated analog circuits**
   Application of OP-AMP-Multivibrator, Schmitt trigger, logarithmic amplifier, antilogamplifier, active filters (-first order, second order, low pass high pass, band pass band stop). 555 timer. (8)

3. **Microprocessors and Microcontroller**
   Architecture of 8085, Data transfer between memory and microprocessor, Types of instruction, Addressing modes, Assembly language programming.
   Basic interfacing concepts- Memory and I/O interfacing, interrupts.
   Programmable peripheral IC 8255A, 8251A. serial and parallel data transfer.
   Architecture of 8051 Microcontroller and its application. Data Acquisition System (DAS). (15)

4. **Semiconductor materials and devices**
   Types of semiconductor materials, silicon wafer preparation, oxidation of the wafer, Basic semiconductor devices, charge storage diode, tunnel diode, metal-semiconductor junction, SCR, Triac, Thyristor. (5)

5. **VLSI fabrication technology**
   Process steps for IC Technology- cleaning, oxidation, diffusion, ion implantation, lithography, etching metallization,
   Fabrication of monolithic IC, VLSI design- design rules, stick diagram, chip assembly and packaging techniques. CMOS fabrications. (7)

References:

1. Network Analysis – Valkenburg
2. Electronic Principles - A.P.Malvino
3. Digital Electronics – Flloyd
4. Introduction to digital Principles - Malvino and Leach
5. Microprocessor Architecture, Programming and Applications with 8085/8085A –R.S. Gaonkar
6. Microprocessor - A. P. Mathur
7. VLSI-Design Techniques for Analog and Digital Circuits - Geiger, Allen and Strader
8. Microwave Devices and Circuits – S.Y. Liao
9. Electromagnetic waves and Radiating Systems - Jordan & Balmain.
10. Advanced Electronics – T. P. Chattopadhyay, CBS Publishers, New Delhi.

Semester-III
Course No. MPC-352
(Credit-4)
Condensed Matter Physics -I
Full marks: 50

1. **Many-body techniques:** Hartree and Hartree - Fock approximations, correlation energy, second quantization formalism, occupation number representation, canonical transformation, Hartree and Hartree - Fock approximations in second quantized notation, application of Hartree-Fock theory to the free electron exchange energy, first order perturbation theory for an electron gas, broken symmetry and Goldstone modes with spin waves, phonons, magnons. (15)

2. **Electron Energy Band Theory:** Bloch theorem, Equivalent and nonequivalent wave vectors and star of a wave vector, Empty lattice band, Fermi surface, orthogonalised plane wave (OPW) method, Augmental plane wave method (APW), Green's function (KKR) method, introduction to density functional technique, relativistic energy bands and spin orbit coupling effects, impurity states and the effective Hamiltonian Method. (10)

3. **Electrons in Solids:** Interacting electron gas, screening, plasma oscillations, Dielectric function of an electric gas ill random phase approximation, limiting cases of Friedel oscillation, strongly interacting Fermi system, elementary introduction to Landau's quasi particle theory of a Fermi liquid, strongly correlated electron gas. (5)

4. **Electronic Properties in Magnetic Field:** k-space analysis of electron motion in uniform magnetic field, idea of closed, open and external orbits, cyclotron resonance, Azbel-Kaner resonance, energy levels and density states in a magnetic field, thickness quantization in 2-D electron gas. (10)

5. **Group Theory in Crystalline Solids:** Crystalline symmetry operators, crystal point groups, classification of point groups according to crystal systems, symmetry of crystalline potential, splitting of ionic levels by crystalline potential of different symmetries -medium and weak field cases, Crystal space groups and representation of symmetric space groups, derivation of equivalent point positions (with examples from triclinic and monoclinic systems), experimental determination of space group. (10)

Reference:

1. The wave mechanics of electrons in metals - S. Raimes
2. Many Electron Theory - S. Raimes
3. Many Body Theory – G.D. Mahan
4. Principles of the Theory of Solids – J.M. Ziman
5. Advanced Field Theory in Solid State Physics - J.M. Ziman
6. Quantum Theory of Solid – C. Kittel
7. Introduction to Solid State Theory – O. Madelung
8. Solid State Physics - Mermin and Azheroft
9. Theoretical Solid State Physics (Vol.-I and II) – A. Hang

10. Group Theory and Quantum Mechanics – M. Tinkhan
11. X-ray Crystallography – Azheroft
12. Elementary Dislocation Theory – Weertman and Weertman
13. Quantum Theory of Solid State – Callaway
14. Crystal Structure Analysis – Buerger
15. Crystallography for Solid State Physics - Verma and Srivastava

Semester-III
Course No. MPC-353
(Credit-4)
Quantum Electronics -I
Lectures: 50
Full marks: 50

1. **Review of Quantum Mechanics:** Time dependent perturbation theory; Broadening of spectral line; Density matrix; Liouville's equations of motion; Reduced density matrix; Maser equation. (8)
2. **Element of Field Quantization:** Lattice vibrations and their quantization, concept of acoustic and optical branch; Thermal excitation of lattice modes; Normal mode expansion of E.M field in a resonator; Quantization of the radiation field; Coherent State; Bunching and Anti bunching of radiation field, Hanbury-Brown-Twiss experiment. (12)
3. **Atom-Field Interaction:** Introduction, Density Matrix approach to the atomic susceptibility, Significance nonlinear susceptibilities; Spontaneous and Induced transitions - Einstien's treatment, Homogeneous and inhomogeneous broadening of spectral line; Hole burning, Lamb dip. (10)
4. **Coherent Interaction of Atom With E.M. Field**: Introduction, Vector representation; Optical Bloch equation; Optical Nutations; Superradiance; photon echoes and self induced transparency. (10)
5. **Lasers**: Optical resonators, Losses optical resonators, Laser oscillation; Gas Lasers; Semiconductor diode lasers and free electron lasers. Q-Switching and mode locking of lasers. (10)

References:

1. Quantum Electrics – A. Yariv
2. Nonlinear Optics – D.L. Mills
3. Nonlinear Optics – E.G. Sauter
4. Quantum Statistical Properties of Radiation – W. Louisell

Semester-III
Course No. MPC-354
(Credit-4)
Nuclear Physics -I

Lectures: 50
Full marks: 50

1. **Nuclear Radiation Detectors:**

Ionizing Radiation: Ionization and transport phenomena in gases – Avalanche multiplication.
Detector Properties: Detection - Energy measurement - Position measurement, Time measurement
Gas Counters: Ionization chambers - Proportional counters - Multi-wire proportional counters (MWPC) – Geiger-Muller counters - Neutron detectors.
Solid State Detectors: Semiconductor detectors - Integrating solid state devices - Surface -barrier detectors.
Scintillation counters: Organic and inorganic scintillators - Theory, characteristics and detection efficiency.
High Energy Particle Detectors: General principles - Nuclear emulsions - Cloud chambers -Bubble chambers - Cerenkov counter.
Nuclear Electronics: Analog and digital pulses -Single pulses - Transient effects in an R-C circuit - Pulse shaping - Linear amplifiers - Pulse height discriminators - Single channel analyzer -Multi-channel analyzer (MCA). (15)

2. **Accelerators:**

Historical Developments: Different types of accelerators - Layout and components of accelerators - Accelerator applications.
Transverse Motion: Hamiltonian for Particle motion in accelerators - Hamiltonian in Frenet - Serret coordinate system - Magnetic field in Frenet-Serret coordinate system - Equation of betatron motion - Particle motion in dipole and quadrupole magnets - Linear betatron motion - Transfer matrix and stability of betatron motion – Sympletic condition – Effect of space – charge force on betatron motion.
Synchrotron Motion: Longitudinal equation of motion –The synchrotron Hamiltonian - The synchrotron mapping - Evolution of synchrotron phase Space ellipse.
Linear Accelerators: Historical milestones - Fundamental properties of accelerating structure - Particle acceleration by EM waves - Longitudinal particle dynamics in Linac - transverse beam dynamics in a Linac.
Principle and Design Details of Accelerators: Basic principle and design of accelerators viz electrostatic, electrodynamics, resonant with special emphasis on microtron, pelletron and cyclotron - Synchrotron radiation sources - Spectrum of the emitted radiation and their applications. (20)

3. **Nuclear Forces:**

The laws of invariance – Boson field theory and phenomenological potentials – Derivation of Yukawa interaction - Few-nucleon systems - Electromagnetic properties of the deuteron and the Rarita-Schwinger equations – The theory of scattering – nucleon-nucleon scattering - polarization in nucleon-nucleon scattering - Scattering matrix - Probing charge distribution with electrons - Form factors - Proton form factors – Deep inelastic electron-proton scattering – Bjorken scaling and patrons - Quarks within the proton - Gluons as mediators of strong interaction. (15)

Reference:

1. Radiation Detection and Measurement - G. F. Knoll (John Wiley & Sons)
2. Techniques for nuclear & particle physics experiments – W. R. Leo (Springer & Verlag)
3. Theoretical Nuclear Physics (Vol.- I & II)– A. de Shalit and H. Feshbach (John Wiley & Sons Ltd)

Semester-III
Course No. MPC-355
(Credit-4)
Quantum Field Theory

Lectures: 50
Full marks: 50

1. Introduction: Concept of fields and field quanta, various kinds of fields and their characteristics, Inadequacies of quantum mechanics and the necessity of field theory. (2)

2. Physical Concept and mathematical formulation of classical fields- a transition from discrete to continuum space-time picture, Field variables, Relativistic version of action principle, Euler-Lagrange equation, Hamiltonian formalism, Symmetries and the conservation laws in Lorentz invariant form, Noether's theorem. (6)

3. Schrödinger field and its special characteristics; Lagrangian formalism and Klein-Gordon field, Spinor field, Electromagnetic field. (3)

4. Concept of second quantization and Field operators, Quantization of (a) Real scalar field, (b) Complex scalar field, (c) Spinor Field and (d) Electromagnetic field; Normal ordering, Time ordered product, Wick's theorem. (14)

5. Local and Global gauge transformations and the corresponding symmetry properties. (5)

6. Interacting quantum fields: Lagrangian formalism, Concept of Feynman diagram and rules, Two-body scattering processes: Applications for electron-muon scattering, Moeller scattering, Bhabha scattering, Compton scattering, pair creation and annihilation. (10)

7. Concept of renormalization in quantum field theory, mass and charge renormalization. (5)

8. Classical solitons and solitary waves: Solitons, Derrik's theorem, domain wall, Sine-Gordon equation, vortex solutions, monopole solutions. (5)

References:

1. Relativistic quantum fields, J.D. Bjorken and S.D. Drell, McGraw-Hill, NY, 1964.
2. An introduction to quantum field theory, M.E. Peskin and D.V. Schroeder.
3. Quantum electro-dynamics, W. Greiner and J. Reinhardt, Springer-Verlag, 1992.
4. Quarks and leptons: An introductory course in modern particle physics, Halgen and Martin, Wiley, 1984.
5. Quantum field theory, Itzykson & Zuber.
6. Quantum field theory, L.H. Ryder, Cambridge Univ. Press.
7. Solitons and Instantons, R. Rajaraman, North-Holland.

Semester-IV

Course No. MPC-41
(Credit-4)
Atomic and Molecular Physics
Lectures: 50
Full marks: 50

1. **One electron Atoms:** Review of Non-relativistic theory and the Dirac theory of the Hydrogen atom, Expansion of the Dirac Hamiltonian in powers of v/c and fine structure, Lamb shift, Hyperfine structure and Isotope shifts, Alkali spectra and elementary ideas of quantum defects, Rydberg and Exotic atoms. (8)
2. **Two-Electron Atoms:** Para and Ortho states, role of spin in two -electron atoms and Pauli's Exclusion Principle, Peturbation and Variational and approximations for the two -electron atoms. Doubly excited states of two -electron atoms, Autoionisation, Auger effect. (7)
3. **Many -Electron Atoms:** Central field approximation, periodic system of elements, Thomas -Fermi model, Hartree-Fock method and the self-consistent field, correction to the central field approximation -L-S and J-J coupling, origin of X-ray spectra. (10)
4. **Interaction of atoms with Radiation:** Selection rules, Line intensities and lifetime of excited states, Line shapes and widths, Pressure and Doppler broadening, Atomic Photoeffect, Atoms in external static fields: Zeeman, Paschen-Bach amd Stark effects. (4)
5. **Molecular structure:** General nature of molecular structure, Rotational, Vibrational and electronic motion, Born-Oppenheimer seperation of electronic and nuclear wavefunctions, LCAO method and the H_2^+-ion, Heitler -London method for H_2, recoil effect in emission and absorption, Mossbauer effect. (5)
6. **Molecular spectra:** Rotational energy levels of diatomic molecules, Vibrational-Rotational sprctra of molecues, Anharmonic oscillator models for diatomic molecules, Pre-dissociation and Dissociation, Rayleigh and Raman scattering, electronic spectra of diatomic molecules, Deslandre's table, Fortrat diagram, Franck -Condon principle, Fluorescence and Phosphorescence, electronic spin and Hund's coupling cases, effect of nuclear spin on diatomic molecules, inversion spectrum of Ammonia. (10)
7. **Laser:** Population Inversion, Spatial and Temporal coherence, Ammonia Maser and He-Ne lasers, Tunable lasers, Laser cooling of atoms. (3)

8. **Magnetic Resonance Spectroscopy:** Principle of magnetic resonance, Electron Spin resonance and Nuclear magnetic resonance, Chemical shifts. (3)

References:

1. Atomic Physics- Bransden and Joachen
2. Fundamental of Atomic Physics- Eisberg
3. Molecular Spectroscopy- Barrow
4. Spectra of Diatomic Molecules- G. Herzberg
5. Chemical Application of Group Theory- Cotton
6. Quantum Mechanics of one & two electron atoms.

Semester-IV

Course No.-MPC-42

(Credit-4)

Dissertation/Project

Full Marks: 50

As per Siksha-Bhavan, Visva-Bharati directive, this course is mandatory for the students of M.Sc. course in Semester-IV. Hence, every member of the faculty is expected to participate in this course in a supervisory role. Each faculty member is expected to supervise at least two students, subject to the availability of the students.

At the end of Semester-II, a list of topics for dissertation/project work will be announced by the department. Students who wish to carry out this course in the Department of Physics may opt for one topic. However, final decision of allocation of topics for dissertation/project works will be made by a departmental committee with H.O.D. as the Convener. The teacher concerned will guide/supervise the dissertation/project work of the student.

Students may opt for carrying out the project/dissertation work outside the Department of Physics, Visva-Bharati- in any science department of Visva-Bharati or any other university / institute recognized by UGC/ DAE/ DST/ CSIR/ AICTE/ ICAR/ ICMR or similar Govt. sponsored organizations/institutes.

This course may start in Semester-III, but the evaluation will be done at the end of Semester-IV. The project/dissertation work may be done outside the usual class hours.

Semester-IV

Course No. MPC-43

(Credit-4)

Computer Application in Physics - II

Full marks: 50

1. **Numerical root finding methods**: Methods for determination of zeros of linear, non-linear polynomial and transcedental equations(Bisection method, Newton Rapson method), Convergent solutions.
2. **Numerical Integration:** Simpson 1/3 rule, Gauss method.
3. **Interpolation:**Finite differences, Interpolation with equally spaced and unevenly spaced points.
4. **Numerical Solution of differential equation:** Ordinary differential equations- Euler and Runge Kutta method, Elementary ideas on the solution of partial differential equations, Crank Nickelson method of the solution of partial differential equation.
5. **Monte Carlo simulation:** Random number generation and quality,Monte Carlo Integration- simple examples, The metropolish algorithm and its application- Ising spin system, simple problem in statistical mechanics.
6. **Matrix manipulation:** Addition and multiplication of matrix, Seidal method of matrix inversion.
7. **Numerical Solution of simultaneous linear equations:** Gaussian elimination.
8. **Curve fitting:** Least square fitting methods.

References:

1. B. P. Demidovich, I. A. Maron: Computational Mathematics
2. W.H Press, S.A. Teukolsky, W.T. Vallering and B. P. Flannery : Numerical Recipes in C
3. Gracia : Numerical methods for Physicists
4. De Vries : A first course in Computational Physics

Semester-IV
Course No. MPC-44
(Credit-4)
General Practical-II
Full marks: 50

1. Determination of resistivity and temperature coefficient of a semiconductor material and to find its band gap (Four Probe method).
2. Use of a Michelson's Interferometer to determine
   (a) Wavelength of monochromatic radiation;
   (b) Separation between the D-lines of Sodium,
   (c) Thickness of a thin film.
3. To study the vibrational coarse structure of Iodine and hence to determine its anharmonicity constant and the dissociation energy in the excited state.
4. Use of Constant Deviation Spectrograph
   (a) To determine the Rydberg Constant from the Balmer lines of Hydrogen.
   (b) To study the Zeeman Effect.
5. Franck-Hertz experiment: study of Ionisation Potentials.
6. To study Faraday effect. (use of He-Ne laser).
7. Determination of the dielectric constant of a material using a series and a parallel resonant circuit.
8. Use of diffraction of ultrasonics to determine the elastic constant of a liquid.
9. Use of Debye Scherrer powder camera to determine the wavelength of X-rays.
10. Measurement of various electrical parameters of a ferroelectric material by PE loop tracer.

Semester-IV

Course No. MPC-451
(Credit-4)
Electronics –II (Practical)
Full marks: 50

1. Design a logarithmic amplifier using (a) diode and (b) matched pair of transistors. Calculate numerical constant η at room temperature from input voltage vs. output voltage curve.
2. Design an antilogarithmic amplifier by using matched pair of transistors and draw input voltage (V_i) vs log of output voltage ($\ln V_o$) curve.
3. Design a regulated power supply without current limiter and with current limiter using (a) transistor as comparator and (b) op - amp as comparator. Draw the regulation characteristics and find-out the output resistance, percentage of regulation and ripple factor before and after regulation.
4. Set up a microwave AM generation and detection experiment. Measure microwave AM index as a function of microwave modulating signal voltage. Measure detected voltage as a function of microwave modulating signal voltage.
5. Design a PLL circuit using IC 565 and study the variation of VCO frequency with time constant (RC). Examine phase locking behavior of the circuit. Measures lock range and capture range of the PLL. Study the FM demodulation performance.
6. Study modulation of a LD through bias current variation and detect the modulating signal by a PD. Study the variation of the detected signal amplitude with the variation of LD bias current.
7. Design a two-bit parallel adder using only NAND gates which is equivalent to IC 7482. Design a BCD adder using 4-bit parallel adder (IC 7483).
8. Design l6-state counter using JK flip flops. Convert the counter to Mod-XX counter using decoding gates.
9. Design a SISO and PISO shift resister using flip flops. Use IC 7495 shift resister and design shift/ring counter.
10. Programming in Microprocessor 8085: Block transfer, Sorting, Arithmetic operation (Multiplication, Division, Square root, Factorial etc.). Interfacing of 8085 with peripheral kits.
11. Design and simulation of IC.

(NEW EXPERIMENTS MAY BE ADDED IN PHASES)

Semester-IV

Course No. MPC-452
(Credit-4)
Condensed Matter Physics-II (Practical)
Full marks: 50

1. Measurement of lattice parameters and indexing of powder photograph.
2. Interpretation of transmission Laue photograph.
3. To determine the magneto-resistance of a Bismuth crystal as a function of magnetic field.
4. To study the ionic conductivity of Alkali halide crystals as a functions of temperature.
5. To study the luminescence behavior and activation energy of Alkali halide crystals.
6. To study the Hall effect of semiconductors.
7. To study the effect of temperature variation on Hall coefficient in semiconductors.
8. To study the characteristics and band gap of semiconductor diode.
9. Study of the properties of magnetic materials by Hysterisis Loop tracer.
10. Study of the susceptibility by Quinck’s Tube Method.
11. ESR measurements of free radicals.

NEW EXPERIMENTS MAY BE ADDED IN PHASES.

Semester-IV

Course No. MPC-453

(Credit-4)

Quantum Electronics –II (Practical)

Full marks: 50

1. To fabricate a precision current controller for a diode laser and study its stability.
2. To study the diode laser drive current versus output power of a laser diode and hence to determine the threshold current for lasing at different working temperature and hence to quantify the dependence of threshold current over working temperature.
3. To fabricate a DC power supply (± 12 volt/± 15 volt) and a photodetector and hence to determine the optical power to voltage conversion ratio of the detector.
4. To determine the temperature tuning rate of a laser diode by using a Fabry-Perot etalon as the frequency marker.
5. To determine the current tuning rate of a laser diode by using a Fabry-Perot etalon as the frequency marker.
6. To study and characterize the intensity profile of a laser beam.
7. To study the saturation absorption line shape of alkali atoms (Rb or Cs) by Lamb dip spectroscopy and hence to determine the separation between the hyperfine peaks.
8. To study the absorption line shape of molecular sample (water vapour /oxygen / acetylene) by using a tunable laser source.
9. To study the transmission of laser beam through optical fiber and figure out the loss due to (i) bending of fiber, (ii) polarization of the coupled beam, (iii) length of the fiber.
10. To determine the saturation intensity of an absorbing sample (preferably Rb/Cs) from the absorption line shape.

NEW EXPERIMENTS WILL BE INTRODUCED IN PHASES.

Semester-IV
Course No. MPC-454
(Credit-4)
Nuclear Physics -II (Practical)
Full marks: 50

1. Determination of half-lives of a radioactive source undergoing complex beta decay.
2. Determination of the lifetime of a long-lived radioactive isotope.
3. Feather’s analysis using GM counter.
4. Study the performance (efficiency, resolution, optimum operating parameters) of a gamma ray spectrometer and determination of the energy of an unknown gamma ray.
5. Energy calibration of a gamma ray spectrometer and determination of the energy of an unknown gamma ray.
6. To determination the mass attenuation coefficient of gamma rays in a given medium.
7. To study Compton scattering using gamma rays of suitable energy.
8. Determination of the decay scheme of a nucleus by gamma-gamma or beta-gamma coincidence method.
9. Construction and testing of a single channel analyzer circuit.
10. To study the performance of a coincidence and anticoincidence circuit.
11. To study the performance of a NaI(TL) scintillation counter by a PC based MCA.

(NEW EXPERIMENTS MAY BE ADDED IN PHASES)

Semester-IV

Course No. MPC-455
(Credit-4)
Particle Physics -I
Lectures: 50
Full marks: 50

1) Basic Concepts: Fundamental particles and their interactions; determination of mass, spin, intrinsic parity; baryon and lepton numbers; fermionic and bosonic fields. (10)

2) Relativistic kinematics: Relativistic kinematics, threshold energy for a process; Mandelstam variables, crossing symmetry, phase space. (5)

3) Dirac Equation: Invariance of Dirac equation, bilinear covariants, properties of gamma matrices (4)

4) Electromagnetic interactions: electron-muon scattering, Compton scattering, electron-positron scattering (6)

5) Weak Interaction: Leptonic, semileptonic and non-leptonic weak decays, selection rules for leptons; quark mixing - CKM matrix; current-current interaction, neutral current, charge current, V-A theory, decay of neutron, muon and charged pion; lepton universality. (15)

6) Neutrino Physics: Dirac and Majorana masses, Beta decay, double beta decay; neutrinoless double beta decay – experimental status and implications; Neutrino detection, solar neutrino problem, neutrino oscillation; atmospheric neutrinos; neutrino masses and mixing, current neutrino experiments; introduction to India-based Neutrino observatory. (10)

Reference:

1. Introduction to Elementary Particles - D.J. Griffiths
2. Quarks and Leptons –F. Halzen and A.D. Martin
3. Quantum Field Theory – L.H. Ryder
4. Advanced Quantum Mechanics – J.J. Sakurai
5. Introduction to High Energy Physics - D.H. Perkins
6. Quarks, Leptons and Gauge Fields – K. Huang
7. Gauge Theory of Elementary Particle Physics – T. Cheng and L. Li
8. The Physics of Massive Neutrinos - B. Kayser, F. Gibrat-Debu and F. Pessier
9. http://pdg.lbl.gov

Semester-IV
Course No. MPC-456
(Credit-4)
Astrophysics
Lectures: 50
Full marks: 50

1. **Basic concept of Astronomy:** (10)
(i) Celestial sphere and related topics.
(ii) Celestial coordinate systems.
(iii) Explanation of astronomical events.
(iv) Distance measurement in astronomy.

2. **Stellar Structure and Evolution:** (12)
(i) Star formation, stellar magnitudes, H-R diagram.
(ii) Virial theorem, gravitational energy, equations of stellar structure and evolution.
(iii) Pre-main sequence evolution, evolution on the main sequence, post main sequence evolution, degeneracy of stellar matter, models of red giants, late stages of stellar evolution, brown dwarfs. Stellar explosions: Nova, Super-nova, Neutron star, White dwarf, Black hole.

3. **Nuclear Astrophysics and Beyond:** 28
(i) Thermonuclear reactions in stars, pp chains and the solar neutrino problem, the CNO cycle, subsequent thermonuclear reactions, helium burning, nucleosynthesis beyond iron, r and s processes.
Static spherically symmetric spacetime: Physical interpretation of metric terms; energy at infinity, gravitational redshift.

Perfect Fluid: Equation of state, equation of motion, TOV equation, stars of uniform density, limit of mass to radius ratio.

Newtonian Stars: Hydrostatic equilibrium, Polytropic equation of state, Lane-Emden equation and its analytic solutions

White dwarf: Electron degeneracy pressure, Chandrasekhar limit.

Neutron Stars: TOV equation applied to neutron stars, Neutron degeneracy pressure, Maximum mass, schematic structure of neutron stars. Pulsars.

Black Holes, Introduction: Creation of black holes, black hole binaries, observational evidence.

Black Hole space-time: Conserved quantities, symmetries and Killing vectors, Schwarzschild black hole, Event Horizon and its nature, infinite red shift, Light cone, Removal of coordinate singularity, Eddington-Finkelstein and Kruskal-Szekres coordinates, Penrose diagram. No hair theorem (statement only)

Kerr metric in Boyer-Lindquist coordinates, event horizons, Ergosphere, Penrose Process, energy extraction from BH, irreducible mass, Dragging of inertial frames

Black Hole Mechanics: Hawking Area Theorem (statement only), surface gravity, four laws of BH thermodynamics, Hawking Radiation (qualitative discussion), BH evaporation.

References:

1) Text book of astronomy and astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.
2) Astrophysics- stars and galaxies, K.D. Abhyankar, Universities press, 2001.
3) Black holes, white dwarfs and neutron stars, S.L. Shapiro and S.A.Teukolsky, John Wiley, 1983.
4) An introduction to the study of stellar structure, S. Chandrasekhar, Dover.
5) The classical theory of fields, L.D. Landau and E.M. Lifshitz, Pergamon, 1975.
6) Relativistic astrophysics, Ya B. Zel'dovich and I.D. Novikov, Vol.-I, University of Chicago press.
7) Theoretical astrophysics, Vol.-I, II and III, T. Padmanabhan, Cambridge.
8) Gravitation and Cosmology: Principles and applications of the General Theory of Relativity- S. Weinberg, John Wiley, 1972.
9) Gravitation: T Padmanabhavan
10) Gravity: Hartle (Pearson Education)
11) A First Course in general relativity – B F Schutz (CUP)
12) General Relativity : R M Wald
13) Lecture notes on general relativity: Sean Carroll, gr-qc/9712019
14) Introduction to General Relativity : G t'Hooft (Freely available)
15) Lecture notes on General Relativity: Mathew Blau (http://www.unine.ch/phys/string/Lecturenotes.html)

Semester-IV

Course No. MPC-457
(Credit-4)
Laser Physics
Lectures: 50
Full marks: 50

1. **Introduction:**
   Einstein coefficients, light amplification, threshold condition, line broadening mechanism, Ammonia beam maser, maser operation. (6)

2. **Coherent states:**
   Minimum uncertainty wave-function, tirne development of minimum uncertainty wave-function, coherent state of the radiation field, properties of coherent states. (6)

3. **Semiclassical laser theory:**
   Electromagnetic field equations, expansion in normal modes of cavity, Lamb's self consistency equations, density matrix equations, polarization of the medium, single mode operation. (6)

4. **Gas laser theory:**
   Polarization of Doppler broadened medium, rate equations and solutions, hole burning, two-mode operation. ` (4)
5. **Multimode Operation:**
   Polarization of the media, free-running operation, locking of beat frequencies between N-modes, two-mode operation. (4)
6. **Quantum theory of laser:**
   Quantization of the radiation field, photon number states, field equation of motion, laser photon statistics, laser linewidth. (6)
7. **Properties of laser beams and types of lasers:**
   Coherence properties of laser light, Spatial and temporal coherence, Directionality, Ruby laser, Helium-Neon laser, Carbon Di-oxide laser, solid state laser, semiconductor diode laser, quantum well lasers, free electron lasers, and dye lasers. (10)
8. **Applications of lasers in Science and Industry:**
   (a) Spatial frequency filtering, Holography, three dimensional hologram, reconstruction.
   (b) Laser induced fusion, laser energy requirements, energy confinement, laser isotope separation.
   (c) Harmonic generation, Stimulated Raman emission, Self focusing.
   (d) Lasers in industries: Application in material processing, laser tracking, LIDAR, lasers in medicine.

   (8)

References:

1. The quantum Theory of Light – R. Loudon
2. Laser: Theory and Applications – K. Thyagrajan and A.K. Ghatak
3. Laser Physics – M. Sargent III, M.O. Scully and W.E. Lamb Jr.
4. Laser Physics – K. Shimoda

Semester-IV
Course No. MPC-461
(Credit-4)
Electronics - III
Lectures: 50
Full marks: 50

1. **Electrical signal generation**
   Microwave devices - Klystrons, magnetrons, traveling wave tubes, solid state devices-GsAs-InP FET, HEMT. (7)

2. **Electrical transmission of signals**
   Radiation from dipole antenna- half wave dipole, radiation from two element array – linear array of antenna. Microwave antenna - Antenna with parabolic reflector, Horn antenna. (6)

3. **Optical signal generation and detection**
   Laser diode, LED, LDR, PIN and Avalanche photodiode, phototransistor. (4)

4. **Optical transmission of signals**
   Principal of light transmission in fibre, Optical confinement in fibre, Numerical aperture, Cladding modes and leaky modes, Cut-off wavelength, Graded index multi mode fibre. Fibre losses - absorption in fibre, scattering losses in fiber. (5)

5. **Optical transmission of electrical signals**
   Transmission of microwave and millimeter wave by light waves. (3)

6. **Electronic communication**
   Review of modulation and detection. Noise in AM systems - DSB-SC, SSB-SC, AM with carrier. Noise in angle modulated systems - FM with noise, comparison with AM system, threshold improvement through De-Emphasis. Digital communication - Pulse coded communication-Sampling theorem, PAM, PWM, PPM, PCM, Delta modulation, ASK, FSK, PSK, DPSK, QPSK, MSK. Multiple access techniques - Computer communication- Different networks like LAN, ISDN, PBX, Medium access sublayer-TDMA, FDMA, ALOHA, Mobile communication. (10)

7. **Optical communication**
   Typical fibre-optic communication system - basic system components, coupling, modulation, multiplexing and coding, repeaters, bandwidth, noise and bit error rate. Dispersion - material dispersion, waveguide dispersion, dispersion-adjusted single mode fiber. (5)

8. **Television**
   Sound and picture transmission- scanning, photoelectric conversion, iconoscope, video signal, transmission and reception, aspect ratio, flicker, vertical resolution, Kell factor, horizontal resolution and video BW, interlaced scanning, video signal components, horizontal sync. And blanking, vertical sync. and blanking, video modulation, VSB, sound modulation. TV channels in CCIR-B system, TV camera, introduction to color TV. (8)

9. LIDAR and SAR

Communication with laser (2)

Reference:

1. Network Analysis – Valkenburg
2. Electronic Principles - A.P.Malvino
3. Digital Electronics – Flloyd
4. Introduction to digital Principles - Malvion and Leach
5. Microwave Devices and Circuits – S.Y. Liao
6. Electromagnetic waves and Radiating Systems - Jordan & Balmain
7. Principles of Communication Systems - Taub and Schilling
8. Optical communication systems - Franz and Jain
9. Electronic communication - D Roody and J Coolen
10. Electronic communication System - George Kennedy
11. Monochrome and Color TV – Gulati
12. Television and Video Engineering - A. M. Dhake
13. Advanced Electronics-T. P. Chattopadhyay, CBS Publishers, New Delhi.

Semester-IV
Course No. MPC-462
(Credit-4)
Condensed Matter Physics - III

Lectures: 50
Full marks: 50

1. **Elastic Properties of Solids:** Thermoelasticity in anisotropic solids, third and fourth order elastic constants, Cauchy relation and condition for isotropy, measurement of elastic constants, homogeneous deformation, theory of elastic constants of crystalline solids. (7)

2. **Lattice Dynamics and Optical Properties of Solids:** Theory of Lattice vibrations in harmonic approximation, equation state of the crystal lattice, phonon-phonon interaction, lattice thermal conductivity of insulators, anharmonicity, thermal expansion and thermal conductivity, electron-phonon scattering, normal and Umklapp processes, Interaction of electrons and phonons with photons, direct and indirect transitions, absorption in insulators, polarizations, one phonon absorption, interaction of electrons with acoustic and optical phonons, polarons. (10)

6. **Disordered systems:** Disorder in condensed matter, substitutional, positional and topographical disorder, short and long range order, Atomic correlation function and structural description of glasses and liquids. (6)

7. **Exotic Solids:** Aperiodic solids and quasi crystals, Fibonacci sequence, Penrose lattices and their extension to 3-dimensions, special carbon solids, nanostructure materials – properties, carbon nanotubes. (2)

8. **Magnetic Properties of Solids:** Review of Heisenberg theory and exchange interaction, spin waves and magnons in ferromagnets, ferromagnetic anisotropy, Block wall, Bloch $T^{\frac{3}{2}}$ law, magnetic ordering, magnetic hysteresis; Antiferromagnetism and super exchange interactions; Magnetic resonance; Magnetic materials. (10)

9. **Superconductivity:** Cooper pairs, BCS ground state from Froehlich electron phonon Hamiltonian, Bogolibuov-Valantin transfprmation, energy gap and critical temperature, macroscopic quantum interference, high temperature superconductors. (8)

10. **Mössbauer effect**: Introduction, Natural line width, Doppler shift, Resonance fluorescence, Recoil energy and recoil momentum, recoilless gamma-ray emission, theory of Mössbauer effect, Debye-Waller factor, Lamb-Mössbauer factor, hyperfine interactions, isomer shift, quadrupole splitting, hyperfine splitting. Applications. (7)

Reference:

1. The wave mechanics of electrons in metals - S. Raimes

2. Principles of the Theory of Solids – J.M. Ziman
3. Quantum Theory of Solid – C. Kittel
4. Introduction to Solid State Theory – O. Medelung
5. Solid State Physics – Aschroft & Mermin
6. Theoretical Solid State Physics (Vol.-I and II) – A. Hang
7. Elementary Dislocation Theory – Weertman and Weertman
8. Quantum Theory of Solid State – Callaway
9. Introduction to the theory of Solid State Physics – J. D. Patterson
10. Solid State Physics – D. W. Snoke
11. Introduction to Superconductivity – M. Tinkham
12. Theory of Magnetism – K. Yoshida, Springer.
13. Introduction to Solid State Physics – 7^{th} Edn. – C. Kittel
14. Introduction to Mössbauer Effect and Applications – V. G. Bhide, Tata-McGraw-Hill.
15. Mössbauer Effect and Transition Metal Chemistry – P. Guetlich, et al., Springer.

Semester-IV
Course No. MPC-463
(Credit-4)
Quantum Electronics - III

Lectures: 50
Full marks: 50

1. **Topics in Nonlinear Optics:** Nonlinear EM field Hamiltonian; Basic concept of nonlinearities; Nonlinear optical susceptibility tensor; Second Harmonic generations; Basic concepts of Parametric amplification; Parametric oscillation; quantum mechanical treatment; Frequency up conversion. Concept of self focusing of the optical beams; Stimulated Raman and Stimulated Brillouin Scattering. (20)

2. **Recent Trends And Developments In Quantum Optical Experiments:** Generation of Squeezed states; Inversionless lasers; optical molasses; Atomic Fountain; Bose-Einstein condenstate. (10)

3. **Guided Wave Optics:** Wave guide modes, planer and periodic waveguides; Directional Coupling; Supermodes; propagation in optical fiber. Nonlinear Schrodinger equation; pulse propagation in a dispersive medium, soliton; Gap soliton. (20)

References:

1. Quantum Electrics – A. Yariv
2. Nonlinear Optics – D.L. Mills
3. Nonlinear Optics – E.G. Sauter
4. Quantum Statistical Properties of Radiation – W. Louisell

Semester-IV
Course No. MPC-464
(Credit-4)
Nuclear Physics –III

Lectures: 50
Full marks: 50

1. **Nuclear Models:**
   Single Particle Shell Model: Determination of wave functions of the nucleus - single particle operator and their expectation values.
   Extended Single Particle Model: Classification of shells - Seniority and reduced *i*-Spin - Configuration mixing - Pairing force theory - Gap equation and ground state properties -Idea of quasi-particles - Simple description of two -Particle shell model spectroscopy.
   Collective Model of Nucleus: Deformable liquid drop and nuclear fission - Shell effects on liquid drop energy - Collective vibrations and excited states – Permanent deformation and collective radiations - Energy levels - Electromagnetic properties of even-even, odd-A deformed nuclei - Nilsson model and equilibrium deformation - Behavior of nuclei at high spin - Back bending. (20)
2. **Nuclear Reactions:**
   Elementary approach to potential scattering theory - S-wave neutron scattering in the compound nuclear reaction model - Derivation and discussion of Breit-Wigner resonance formula - Single level single channel R-matrix (R-function) theory - Statistical model of compound nuclear reaction - Pre-equilibrium reactions - Discussion of direct reactions - Plane wave theory of deuteron - Stripping in zero range approximation - Spectroscopic factor and determination of nuclear level properties - Single nucleon transfer reactions - Theory of average cross-sections - Properties of optical potentials - Heavy-ion collisions - Features of medium and low energy heavy-ion elastic scattering – Diffraction models – Nuclear fission and extended liquid drop model. Thermonuclear reactions (pp-chain and CNO cycle). (22)
3. **Applications of Nuclear Physics:**
   Nuclear Reactors: Fission reactors - fusion reactors - muon-catalyzed fusion, Medical physics- radiation dosimetry. (8)

Reference:

1. Introduction to Nuclear Reactions – Satchler
2. Nuclear Reactions – Jackson
3. Direct Nuclear Reactions – Glendenning
4. Theoretical Nuclear Physics (Vol.- I & II)– de Shalit and Feshbach
5. Pre-Equilibrium Nuclear Reactions – Gadioli and Hodgson
6. Nuclear Structure – Eisenberg and Greiner (Vol I)
7. Nuclear Models – Greiner.

Semester-IV

Course No. MPC-465

(Credit-4)

Particle Physics –II

Lectures: 50

Full marks: 50

1. Space-time and Internal Symmetries: Parity, charge conjugation and time reversal symmetries; $K^0 - \bar{K}^0$ mixing, CP violation; CPT theorem; Lie groups and Lie algebra; Lorentz group; SU(2) and SU(3) groups; introductory idea of supersymmetry. (15)

2. Quark Model: Isospin and strangeness, baryon and meson multiplets, concept of color; symmetry breaking; Gell-Mann-Okubo mass formula; constituent quark model – construction of wave function of hadrons, mass and magnetic moments of hadrons. (8)

3. Gauge Theory: Abelian and non-abelian gauge invariance - U(1), SU(2), SU(3) and O(3); colour gauge invariance and QCD; Evolution of gauge coupling, Asymptotic freedom and confinement. (10)

4. Standard Model: Spontaneous symmetry breaking and Higgs mechanism; Standard Model of electroweak interaction; fermion mass. (10)

5. Beyond the Standard Model: Unification of strong weak and electromagnetic interaction gauge coupling unification, proton decay – implication and experimental; hierarchy problem and supersymmetry, dark matter, colliding beam experiments and search for new physics – Tevatron, LHC - current status. (7)

Reference:

1. Introduction to Elementary Particles - D.J. Griffiths
2. Quarks and Leptons –F. Halzen and A.D. Martin
3. Quantum Field Theory – L.H. Ryder
4. Advanced Quantum Mechanics – J.J. Sakurai
5. Introduction to High Energy Physics - D.H. Perkins
6. Quarks, Leptons and Gauge Fields – K. Huang
7. Gauge Theory of Elementary Particle Physics – T. Cheng and L. Li
8. http://pdg.lbl.gov

Semester-IV
Course No. MPC-466
(Credit-4)
Cosmology
Lectures: 50
Full marks: 50

1. Introduction to Cosmology: Hubble's law, Cosmological Principle, observational basis for cosmological theories, a brief introduction to big bang cosmology. (5)

2. Homogeneous Isotropic world models: Derivation of Friedmann models and their properties, radiation dominated and matter dominated universe, the distance scale, the age of the universe, the density parameter. (5)

3. Physics of the Big Bang: thermal history of the universe, cosmological nucleosynthesis, the cosmic microwave background radiation (CMBR), the decoupling era, large- and small-scale anisotropy in the CMBR. (5)

4. Achievements and problems of the Standard Model: horizon problem, flatness problem, inflation. (5)

5. Galaxy: Milky Way as a galaxy, galaxy types, classification and morphology of galaxies, dynamics of galaxies, rotation curves and dark matter, galaxy properties, scaling relations. (5)

6. Large scale structure of the Universe: redshift surveys of galaxies, measures of the galaxy distribution, correlation functions and power spectra, topological measures of galaxy distribution. (5)

7. Large scale structure formation: inhomogeneities in the universe, gravitational instability, linear theory for description and evolution of density fluctuations, non-linear structure formation. (5)

8. Galaxy formation: the CDM model, biasing and the mean mass density, top-down and bottom-up galaxy formation, semi analytic models. (5)

9. Reionization of the Universe: the first stars, the reionization process. (5)

10. Cosmological Parameters: estimation of cosmological parameters from clusters of galaxies, redshift surveys and angular fluctuations of the CMBR. (5)

Recommended books:

(a) *Principles of Physical Cosmology*, P.J.E. Peebles, Princeton University Press, 1993.
(b) *Cosmological Physics*, John A. Peacock, Cambridge University Press, 1999
(c) *Cosmology*, Steven Weinberg, Oxford University Press, 2008
(d) *Modern Cosmology*, Scott Dodelson, Academic Press, 2006
(e) *The Early Universe*, E.W. Kolb and M.S. Turner, Addision-Wesley reading, 1990.
(f) *Introduction to Cosmology*, J.V. Narlikar, Cambridge university press, 1993.
(g) *Theoretical Cosmology*- A.K. Raychaudhuri, Oxford press, 1979.

Syllabus

of

Elective Courses for

M. Sc. in Physics

SEVERAL ELECTIVE COURSES FOR SEM-III WILL BE OFFERRED AT THE END OF SEM-II. PRESENTLY, THERE ARE FIVE ELECTIVE COURSES IN THE SYLLABUS. SOME NEW COURSES MAY BE ADDED IN PHASES. HOWEVER, THE NUMBER OF ELECTIVE COURSES OFFERRED FOR SEM-III EVERY YEAR WILL BE DECIDED BY THE DEPARTMENT. OUT OF THE OFFERRED COURSES, STUDENTS HAVE TO SELECT ONLY ONE COURSE FOR SEM-III. HOWEVER, FINAL DECISION IN THIS REGARD WILL BE MADE BY A COMMITTEE WITH H.O.D. AS THE CONVENER.

Semester-III
Course No. MPE-361
(Credit-4)
Feynman Path Integrals in Quantum Mechanics

Lectures: 50
Full marks: 50

1. Introduction: Fermats principle of least action, Hamilton's principle of least action,Going from Classical mechanics to Quantum mechanics, A brief Review of Quantum Mechanics.(5)

2. Time Evoluation: The time evoluation operator, Kernel, The Trotter product formula and the Dirac short time kernel, The path integral representation of the kernel, The path integral representation of the partition function, Derivation of Schrodinger equation from path integral. (10)

3. Gaussian path integrals and determinant: The free particle, The harmonic oscillator, Gaussian path integrals and determinants. (10)

4. Perturbation theory: The perturbative expansion, Time-dependent perturbation and transition amplitudes (First order and higher order terms). (8)

5. Scattering: The scattering of an electron by an atom, Born approximation, The differential cross section for scattering. (8)

6. Generating functionals and perturbative expansions: The generating functional, Greens functions and generating functionals for Quadratic theories, Greens funtion for free particle and harmonic oscillators, Perturbative expansion and generating functionals, The stationary approximation for oscillatory integrals, The semiclassical approximation. (6)

7. Quantum field theory: A brief introduction to the basic ideas of Quantum field theory. (3)

References:

1. R. P. Feynman and A.R. Hibbs: Quantum Mechanics and Path integrals
2. L.S. Schulman: Techniques and Applications of Path Integration
3. R. P. Feynman: Statistical Mechanics
4. R. P. Feynman: Space time approach to Non-relativistic Quantum Mechanics -Rev. Mod. Phys. 20 367 (1948).
5. J . Zinn-Justin: Path Integral in Quantum Mechanics.

Semester-III
Course No. MPE-362
(Credit-4)
Physics of Dense Matter
Lectures: 50
Full marks: 50

1. Relatively Low Density Region: (10)
a) Hartree and Hartree-Fock Equations- use of Variational method; Application to Bulk nuclear matter and finite nuclei.
b) Thomas-Fermi and Thomas-Fermi-Dirac equations.
c) Thermal Thomas-Fermi and Thermal Hartree-Fock equations.

2. Matter of Moderate Density-I: (15)
a) Nuclear Skyrme interaction; Direct and Exchange interactions; Nuclear symmetry energy; Nuclear compressibility.
b) Harrison-Wheeler (HW), Baym-Pethick-Sutherland (BPS) and Baym-Bethe-Pethick (BBP) equation of states.
c) Nuclear Coulomb and Lattice energies.

3. Matter of Moderate Density-II: (10)
a) Nucleon-Nucleon scattering and nuclear realistic potential.
b) Lipmann-Schwinger equation.
c) Reid soft and hard core potentials.
d) Brueckner-Bethe-Goldstone equation.

4. Matter at High and Ultra-High Density: (15)
a) Dirac equation and relativistic Hartree and Hartree-Fock equations with some application to bulk nuclear matter and finite nuclei.
b) Mean field theory for nuclear matter with sigma-omega-rho meson exchange.
c) Hyperons in dense nuclear matter.
d) Pion-nucleon interaction and the possibility of pion condensation.
e) Quark matter: Quark-hadron phase transition at high density; Study of dense quark matter with relativistic Hartree-Fock equation and relativistic version of Landau theory of Fermi liquid at zero temperature.

Books Recommended:

1. Theory of finite Fermi system and applications to atomic nuclei, A.B. Migdal, Wiley Inter-Science.
2. Collision theory, M.L. Goldberger and K.M. Watson, Wiley.
3. K.A. Brueckner, in “The many-body problem”, Ed. C. Dewitt, Dunod Cie, Paris.
4. Physics of dense matter, Y.S. Leung, World Scientific.
5. S.L. Shapiro and S.A. Teukolsky, Black Holes, White Dwarfs and Neutron Stars, John Wiley and Sons, New York, (1983)
6. Recent progress in many body theory, J.G. Zabolitsky, M. De Lano, M. Fortes and J.W. Clark, Springer-Verlag.
7. Quantum theory of many-particle systems, A.L. Fetter and J.D. Walecka, Mc. Graw-Hill.

8. Theoretical nuclear and sub-nuclear physics, J.D. Walecka, Oxford Univ. Press.
9. Meson in nuclei, Vol.-I, M. Rho and D. Wilkinson (eds.), North-Holland.
10. G. Baym and D.K. Campbell, Mesons in nuclei-III, (M.Rho and D. Wilkinson eds.), North-Holland.
11. Models of the nuclei, R.K. Bhaduri, Addision-Wesley Publishing Co.
12. K.A. Brueckner, "Theory of nuclear structure", in The Many-Body Problem, (ed. C. Dewitt), John Wiley.
13. L.S. Celenza and C.M. Shakin, Relativistic nuclear physics, World Scientific.
14. Quantum many-particle system, J.W. Negele and H. Orland, Addision-Wiesly.
15. N.K. Glendenning, Compact Stars: Nuclear physics, particle physics and gravitation, Springer.
16. P. Ring and P. Schuck, The nuclear many-body problem, Springer-Verlag.
17. Matter at high densities in astrophysics- compact stars and the equation of states- In Honor of Friedrich Hund's 100th Birthday, Springer.

Semester-III
Course No. MPE-363
(Credit-4)
Topics In Modern Quantum Mechanics
Lectures: 50
Full marks: 50

1. Self-adjoint operators: Symmetric(Hermitian) operator; Role of boundary condition; Domain of an operator; von Neumann criteria & Selfadjoint extensions; Examples: (i) Momentum operator on the half-line, (ii) Simple Harmonic Oscillator in two/three dimensions; Physical relevance. (5)
2. Supersymmetric Quantum Mechanics(SUSY QM): Hamiltonian formulation of SUSY QM; Factorization & hierarchy of Hamiltonians; Shape invariance & exactly solvable potentials; Applications. (5)
3. Scattering theory: The Lippmann-Schwinger equation; The Born approximation; Optical theorem; Eikonal approximation; Free particle states: Plane waves versus spherical waves; Method of partial waves; Low energy scattering & bound states; Resonance scattering; Identical particles & scattering; Symmetry considerations in scattering; Time dependent formulation of scattering; Inelastics Electron-Atom Scattering; Coulomb Scattering. (10)
4. Path Integral Quantization: Paths in classical mechanics; Path integrals as the sum over paths; Feynman's formulation of path integral quantization; Path integral quantization of simple harmonic oscillator & a few other simple systems; Aharonov-Bohm effect & path integrals; Canonical versus path integral quantization; A brief overview on the applications of the technique to QFT & statistical mechanics. (10)
5. Quantum Entanglement: Qubit; spin- 1/2, photon polarizations; Density operators; Pure vs. mixed ensemble; Schmidt decomposition; Entanglement; Correlations in spin singlet states; Einstein's locality principle and hidden variables; The Bell inequality; Quantum entanglement & Bell inequality; Experiments & loopholes; Usage of entanglement dense coding, quantum teleportation etc. (10)
6. Coherent & Squeezed states: Definitions of coherent & squeezed states; Harmonic oscillator coherent & squeezed states; Discourse on equivalence among different definitions; Application of coherent and squeezed states to different branches of physics. (5)
7. Geometric Phases: Adiabatic Change in Quantum Mechanics; Pancharatnam Phase; Berry phase; Experimental verifications; Aharonov-Bohm effect; Jahn-Teller effect; Hannay's angle-Geometric phase in classical mechanics. (5)

References:

1. Modern Quantum Mechanics(Revised Edition), J. J. Sakurai, Addison-Wesley.
2. Supersymmetry and Quantum Mechanics, F. Cooper, A. Khare and U. Sukhatme, Physics Reports 251 (1995) 267[hep-th/9405029]; Supersymmetry in Quantum Mechanics, F. Cooper, A. Khare and U. Sukhatme, World Scientific Publishing Company.

3. R. Dutt, A. Khare and U. Sukhatme, Am. Jour. Phys. 56 (1988) 163.
4. Guy Bonneau, Jacques Faraut and Galliano Valent, Self-adjoint extensions of operators and the teaching of quantum mechanics, Am. Jour. Phys. 69 (2001)322.
5. Geometric Phases in Physics, A. Shapere and F. Wilczek, World Scientific.
6. Quantum Mechanics and Path Integrals: Emended edition, Richard P. Feynman and A. R. Hibbs, Daniel F. Styler, Dover Books on Physics.
7. Coherent States, J. R. Klauder and B. Skagerstam, World Scientific.
8. Lecture notes on Quantum Entanglement, J. Preskill, http://www.theory.caltech.edu/ preskill/ph229/

Semester-III
Course No. MPE-364
(Credit-4)
Plasma Physics
Lectures: 50
Full marks: 50

1. Introduction
(a) Definition of plasma as an ionized gas, quasi-neutrality, collective behaviour of plasma particles, Debye shielding, plasma frequency, characteristic length and time scales of a plasma, collision frequency.
(b) Plasma sources : Laboratory sources of plasma, Natural sources of plasma,Van Allen radiation belts, the ionosphere, the sun and its atmosphere, plasma beyond solar system.
(c) Theoretical description : single particle motion in prescribed electric and magnetic fields, fluid description, statistical mechanical description. (6)

2. Single Particle Motion
(a) Motion of charged particles in a constant and uniform magnetic and electric fields, magnetic moment of a gyrating charged particle, concept of guiding centre, drift velocities of the guiding centre in combined electric and magnetic fields, gravitational field, currents associated with drift velocities.
(b) Particle motion in a constant but spatially non-uniform magnetic field, average force acting on a charged particle in a non-uniform magnetic field, Adiabataic invariants, magnetic mirror effect, confinement of plasma in a mirror configuration, loss cone, Fermi- acceleration, Gradient and curvature drifts, confinement of plasma in earth's magnetic fields.
(c) Particle motion in slowly time-varying electric fields, polarization drift and current, plasma as a dielectric medium.
(d) slowly time-varying magnetic field and space varying electric field, adiabatic invariant andmagnetic heating of a plasma.
(8)

3. Description of Plasma as a Fluid
(a) Fluid models of plasma : Equation of continuity, Momentum equation, cold and warm plasma models, concept of pressure tensor, equation of state, fluid drifts and diamagnetic current.
(b) Magnetohydrodynamics : MHD equations, generalized Ohm's law, Induction equation-magnetic Reynolds number, diffusion of magnetic field lines in a resistive plasma, "Frozen-in" magnetic fields, MHD equilibria, force-free magnetic fields, Hydromagnetic waves-Alfven and magnetosonic waves.
(c) Plasma confinement in magnetic fields: Pinch effect, theta pinch, Z-pinch, Bennett relation for Z-pinch, general screw pinch, safety factor.
(8)

4. Waves in a Two-Fluid Plasma:
Parallel and perpendicular propagating waves, longitudinal and transverse waves, electrostatic and electromagnetic waves.
(a) Unmagnetized Plasma : electron plasma oscillations, Langmuir waves, ion acoustic and ion plasma waves, two stream instability, electromagnetic waves in an unmagnetized plasma.

(b) Waves in a magnetized Plasma : Right and left circularly polarized waves, Ordinary (O) and extraordinary (X) waves, Whistlers, Helicons and Faraday rotation.

(12)

5. Collisions and Diffusion in weakly ionized plasmas
   Ambipolar diffusion, Fick's law, diffusion across magnetic fields.

(4)

6. Plasma Kinetic Theory :
   Distribution function, its evolution in phase space- Boltzmann and Vlasov equations, Physical picture of Landau damping.

(6)

7. Experimental techniques :
   Plasma in a discharge tube, Langmuir probe, Measurement of density and temperature, Microwave measurements.

(6)

References :

Introduction to Plasma Physics and Controlled Fusion : Francis F. Chen.

Fundamentals of Plasma Physics : J. A. Bittencourt.

Principles of Plasma Physics : Krall and Trivelpiece.

Semester-III
Course No. MPE-365
(Credit-4)
TECHNIQUES OF EXPERIMENTAL PHYSICS

LECTURES: 50
Full marks: 50

Group A: Experimental Techniques for Condensed Matter Physics

Full marks - 25: Lectures – 25

1. Standard methods for the preparation of different kind of materials. (2)
2. X-ray diffractometer, Phase identification from x-ray diffrractogram, Calculation of lattice parameters, strain, density and grain size. (3)
3. Fundamentals of electron microscopy, Scanning electron microscope and Transmission electron microscope, Structural Characterization of materials by SEM, TEM, AFM. (4)
4. Magnetic Measurements: Force Methods – Gouy Method, Faraday Method and Alternating Force Magnetometer (AFM); Induction Methods – AC Induction, Vibrating Sample Magnetometer (VSM), Superconducting Susceptometer (SQUID); Measureable Parameters; Calibration Materials; Examples. (4)
5. Heat Capacity Calorimetry: Thermodynamics of Magnetic Systems; What one can learn from Heat Capacity – Phase Transition, Lattice dimensionality, Type of Spin-Spin Interaction, Schottky Anomaly, Spin Wave Excitation, Magnetocaloric Effect; Differential Scanning Calorimeter (DSC), Adiabatic Calorimeter, AC Calorimeter, PPMS; Examples. (4)
6. Mössbauer Spectroscopy: Introduction to Mössbauer Effect, Debye-Waller factor, Lamb-Mössbauer factor, hyperfine interaction parameters (isomer shift, quadrupole shift, quadrupole splitting); Applications in Spin Transition Materials, Magnetic Materials; Examples. (4)
7. Experimental techniques for Optical, Electrical and Dielectric characterization of materials. (4)

Group B: Experimental Techniques for Nuclear and Particle Physics:

Full marks - 25: Lectures - 25

1) **Physics of particle detection:** Passage of particles through matter – electromagnetic and nuclear interactions, energy loss, stopping power, radiation length, interaction length. (5)
2) **Detectors - I:** Geiger-Muller counter, proportional chamber, Inorganic and Organic scintillators, semiconductors, photographic emulsions, solid state nuclear track detector (SSNTD), resistive plate chamber. (8)
3) **Detectors – II:** Detectors for colliding beam experiments – tracking, calorimetry, time of flight, position sensitive detector, particle identification; detectors for non-accelerator experiments – proton decay, neutrino experiments, anti-matter search. (5)
4) **Detectors - III:** spark chamber, cloud chamber, bubble chamber, plastic sheet, mica. (2)
5) Statistics for nuclear and particle physics (5)

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4. Radiation Detectors - Knoll
5. Review of Particle Physics, Particle Data Group, http://pdg.lbl.gov
6. Experimental Techniques in High Energy Physics, Thomas Ferbel
7. Statistics for nuclear and particle physics, Louis Lyons