M.Sc.

Sl. No.	Name of the Paper	Paper Type	Paper Code	Credits	Periods/week
Semester I					
1	Quantum Mechanics I	Core	PHM11C	4	4
2	Mathematical Physics I	Core	PHM-12C	4	4
3	Classical Mechanics	Core	PHM-13C	4	4
4	Electronics	CBE	PHM-11E	4	4
5	Lab I	Lab	PHM-11L	6	12
Semester II					
1	Condensed Matter Physics I	Core	PHM-21C	4	4
2	Quantum Mechanics II	Core	PHM-22C	4	4
3	Electrodynamics	Core	PHM-23C	4	4
4	Mathematical Physics II	CBE	PHM-21E	4	4
5	Experimental Techniques	SEC	PHM-21A	4	4
6	Lab II	Lab	PHM-21L	6	12
Semester III					
Material Science Specialization					
1	Atomic & Molecular Physics	Core	PHM-31C	3	3
2	Nuclear & Particle Physics	Core	PHM-32C	3	3
3	Advanced Topics in Material Science	Core	PHM-33CM	4	4
4	Lab III	Lab	PHM-31L	6	12
5	Numerical Analysis & Programming	AEC	PHM-31A	4	4
Laser &Spectroscopy Specialization					
1	Atomic & Molecular Physics	Core	PHM-31C	3	3
2	Nuclear & Particle Physics	Core	PHM-32C	3	3
3	Laser Physics	Core	PHM-33CL	4	4
4	Lab III	Lab	PHM-31L	6	12
5	Numerical Analysis & Programming	AEC	PHM-31A	4	4
Theory Specialization					
1	Atomic & Molecular Physics	Core	PHM-31C	3	3

2	Nuclear & Particle Physics	Core	PHM-32C	3	3
3	Classical Field Theory	Core	PHM-33CT	4	4
4	Lab III	Lab	PHM-31L	6	12
5	Numerical Analysis & Programming	AEC	PHM-31A	4	4
Electives					
6	Characterization of Materials	CBE	PHM-31E	4	4
7	Photonics	CBE	PHM-32E	4	4
8	General Relativity	CBE	PHM-33E	4	4
Semester IV					
Material Science Specialization					
1	Statistical Mechanics	Core	PHM-41C	4	4
2	Condensed Matter Physics II	Core	PHM-42C	4	4
3	Phys &Tech of Semiconductor Devices	Core	PHM-43CM	4	4
4	Project	Project	PHM-44	4	
Laser &Spectroscopy Specialization					
1	Statistical Mechanics	Core	PHM-41C	4	4
2	Condensed Matter Physics II	Core	PHM-42C	4	4
3	Quantum Optics	Core	PHM-43CL	4	4
4	Project	Project	PHM-44C	4	
Theory Specialization					
1	Statistical Mechanics	Core	PHM-41C	4	4
2	Condensed Matter Physics II	Core	PHM-42C	4	4
3	Particle Physics	Core	PHM-43CT	4	4
4	Project	Project	PHM-44C	4	
Electives					
5	Physics of Novel Materials	CBE	PHM-41E	4	4
6	Laser Spectroscopy	CBE	PHM-42E	4	4
7	Quantum Field Theory	CBE	PHM-43E	4	4

Semester I

Core Course **Quantum Mechanics I** **PHM-11C**

Unit I: Mathematical Tools

Brief introduction to origins of quantum Physics. Wave packets. Dirac notation. Operators, their eigenvalues and eigenfunctions, orthonormality, completeness and closure. Generalized uncertainty principle. Unitary transformations, change of basis. Matrix Representation of operators. Continuous basis, position and momentum representation and their connection.Parity operator.

Unit II: Fundamental Concepts of Quantum Mechanics

Basic postulates of quantum mechanics. Measurement. Time evolution of system’s state. Schr¨odinger, Heisenberg and interaction pictures. Density operator. Pure state and mixed state density operators. Discrete and continuous spectra in 1-D. Solution of 1-D harmonic oscillator using algebraic method.

Unit III: Angular Momentum

Orbital, Spin and total angular momentum operators. Pauli spin matrices, their Commutation relations. Eigenvalues and eigenfunctions of L 2 and L z . Angular momentum as generator of rotation. Addition of angular momenta. Clebsch-Gordon coeficients. L-S coupling.

Unit IV: Identical Particles

Many particle systems, systems of identical particles, exchange degeneracy, symmetrization postulate, construction of symmetric and anti-symmetric wave functions from unsymmetrized functions. The Puli exclusion principle. Introduction to second quantization. Creation and annihilation operators for Fermions and Bosons. Fock states.

Reference Books:

1. Quantum Mechanics : N. Zettili
2. Quantum Mechanics : Franz Schwabl
3. Modern Quantum Mechanics : J.J.Sakurai
4. Priciples of Quantum Mechanics : P. A. M. Dirac
5. Quantum Mechanics : Bohm

Semester I

Core Course **Mathematical Physics I** **PHM-12C**

Unit I: Complex Analysis

Advanced complex analysis : Brief description of functions of complex variables with examples, mappings, limits, continuity, differentiation, analytic functions, branch cut, branch point, line integral, simply and multiply connected domains, Taylor and Laurent series : convergence, residues and poles, contour integrals, 2-dimensional Laplace equation

Unit II: Partial Differential Equations

Partial differential equations : 1-dimensional - vibrating string, heat flow, 2-dimensional - vibrating membrane, 3-dimensional – Wave equation, Laplace equation : potential theory, diffusion equation

Unit III: Green's Function

Green's function : Method for boundary value problems, GF in one dimension, eigenfunction expansion of Green's function, multidimensional GF's, examples : elliptic, parabolic and hyperbolic equations

Unit IV: Integral equations

Integral equations : Classification, Fredholm and Volterra integral equations, Transformation of a differential equation into integral eq., Hermitian Kernel, degenerate kernels, Fredholm alternative, integral transforms, successive approximations, successive substitution, resolvent kernel, Hilbert-Schmitt theory

Unit V: Tensor Analysis

Contravariant vectors, Covariant vectors, Coordinate transformation from one coordinate system to another, Various coordinate systems (Cartesian, Cylindrical, Spherical Polar, Oblique axes etc.), Addition and subtraction of tensors, symmetric/anti-symmetric tensor, outer multiplication, contraction, inner multiplication, quotient theorem. Inertia tensor, definition, derivation of expression, calculation of it's components, stress, strain and elastic constant tensors, Chistoffel symbols, Riemann curvature tensor

Reference Books:

1. Complex variables and applications by Churchill & Brown, IV Ed, MGH
2. Mathematical Physics, Sadri Hassani, II Ed., Springer
3. Mathematical methods for physicists, 6th Ed., Arfken& Weber, Elsevier
4. Tensors by De, Sheikh and Sengupta, Narosa.

Semester I

Core Course **Classical Mechanics** **PHM-13C**

Unit I: Lagrangian Formalism

Newtonian mechanics and its limitations. Constrained motion. Constraints and their classification. Principle of virtual work. D' Alembert's principle. Generalised coordinates. Deduction of Lagrange's equations from D' Alembert's Principle. Generalised momenta and energy. Cyclic or ignorable coordinates. Rayleigh' s dissipation function. Integrals of motion. Symmetries of space and time with conservation laws.

Unit II: Hamiltonian formalism

Principle of least action. Hamilton's principle. The calculus of variations. Derivation of Hamilton's equations of motion for holonomic systems from Hamilton's principle. Hamilton's principle and characteristic functions.

Unit III: Canonical Transformation

Canonical Transformations. Generating functions. Poisson bracket. Poisson's Theorem. Invariance of PB under canonical transformations. Angular momentum PBs. Hamilton-Jacobi equation. Connection with canonical transformation. Problems.

Unit IV: Rigid Body Dynamics

Rotational motion, moments of inertia, torque. Euler's theorem, Euler angles. Symmetric top. Gyroscopes and their applications.

Unit V: Small Oscillations and Nonlinear Dynamics

Small Oscillations. Normal modes and coordinates. Applications. Perturbations and KAM theorem, Attractors, Chaotic trajectories and Liapunov exponents, Poincare maps, bifuractions, Logistic equation, Fractals and dimensionality

Reference Books:

1. Classical Mechanics: H. Goldstein.
2. Mechanics: L. D. Landau and E. M. Lifshitz
3. Classical Mechanics: N.C.Rana and P.S.Joag.
4. Theoretical Mechanics: Murray Spiegel.
5. Classical Mechanics Systems of Particles and Hamiltonian Dynamics:Walter Greiner

Semester I

Choice Based Elective **Electronics** **PHM-11E**

Unit I: Semiconductor Devices I

Semiconducting Materials, conduction in semiconductors, Charge densities in a semiconductors, PN junction, space charge and electric field distribution at junctions, forward and reverse biased conditions, Space charge capacitance, varactor diode, Zener and avalanche breakdowns, zener diode, tunnel diode, photodiode, LED, p-n-p-n devices and their characteristics, SCR.

Unit II: Semiconductor Devices II

Transistors: Bipolar junction Transistor (BJT), Ebers Moll Model, Analysis of CE amplifier using h-parameters, The T-network equivalent circuit, constants of CB and CE amplifier using emitter, base, collector resistance, Biasing technique to BJT, stabilization factor, temperature stabilization, operating point, fixed bias, emitter feedback bias, voltage feedback bias. Field-Effect Transistors (FET) and MOSFET: Structure, Working, Derivations of the equations for I-V characteristics under different conditions.

Unit III: Feedback Principle

Negative feedback, effect of negative feedback on input/output resistances and voltage gain, gain stabilization, effect of negative feedback on band width, voltage series feedback, voltage shunt feedback applied to BJT, current series feedback, current shunt feedback applied to BJT

Unit IV: Microwave Electronics

Microwaves, Principle of velocity modulation and bunching of electrons, Basic principles of two cavity klystrons and Reflex Klystrons, operation of magnetrons, characteristics of microwave diode.

Reference Books:

1. Electronic Fundamentals and Applications : John D. Ryder
2. Electronic Devices and Circuits : Millman and Halkins
3. Solid State Electronic Devices : Ben G. Streetman
4. Electronics : Ramabhadran S.
5. Electronics Devices and Circuit theory : Boylested and Nashelsky
6. Pulse, Digital and Switching Waveforms : Millman and Taub
7. Fundamental of Transistor : S.W. Amos
8. Microwave Principle : W.J. Reich
9. Microwaves : K.L. Gupta
10. Introduction to Microwave : G.J.Wheeler;
11. Semiconductor Devices- Physics and Tecnology : S.M. Sze.

<u>Semester I</u>

Physics Practical **Lab I** **PHM-11L**

List of Experiments :

1. PN Junction : To find the band gap of the semiconductor
2. CE Amplifier (Bread Board) : To find bandwidth of capacitive coupled common emitter amplifier
3. Transistor Biasing : To study various biasing techniques, viz i) self bias ii) fixed bias, iii) voltage divider biasing, and to find the best biasing by observing the temperature effect on output waveform
4. FET : To find input and transfer characteristics of Field Effect Transistor
5. MOSFET : To find input and transfer characteristics of MOSFET
6. Op-Amp : To make inverting/non-inverting amplifiers, buffer, integrator and differentiator circuits using operational amplifier
7. To study Feedback in Transistors : a) series-series b) series-shunt c) shunt-series iv) shunt-shunt feedbacks
8. IC555 (BB) : To make astable and monostable vibrator using IC555
9. Phase Shift Oscillator (BB) : To make RC phase shift oscillator using 3 and 4 RC networks and compare experimental and theoretical frequencies
10. To study Amplitude Modulation & Demodulation and to calculate modulation index
11. To make Astable multivibrator using bipolar transistor
12. Optoelectronic kit : to study characteristics of i) Light Emitting Diode, ii) Temperature Dependent Resistance, iii) light dependent transistor
13. To study Analog to Digital conversion
14. To study Digital to Analog conversion
15. To study Frequency Modulation & Demodulation and to calculate modulation index
16. To study PAM (Pulse Amplitude Modulation) circuit
17. To study PCM (Pulse Code Modulation) circuit
18. To study PWM (Pulse Width Modulation) and PPM (Pulse Position Modulation) circuits

<u>Semester II</u>

Core Course **Condensed Matter Physics I** **PHM-21C**

Unit I: Bonding in crystals

Covalent, ionic, metallic, hydrogen bond, van der Waal's bond and the Madelung constant. Crystalline solids, unit cell, primitive cell, Bravais lattices, Miller indices, closed packed structures. Atomic radius, lattice constant and density. Connection between orbital symmetry and crystal structure. Scattering from periodic structures, reciprocal lattice, Brillouin Zones.

Unit II: Phonons - Lattice Dynamics and Thermal Properties.

Lattice dynamics of atoms in crystals, vibrations of monoatomic and diatomic linear chains, acoustic and optical phonon modes, density of states, thermal properties of crystal lattices, thermal energy of the harmonic oscillator, specific heat capacity of the lattice, Debye theory of specific heats.

Unit III: Free Electron Theory

Free electrons in solids, density of states, Fermi surface, Fermi gas at T=0 K, Fermi statistics, specific heat capacity of electrons in metals, thermionic emission of electrons from metals.

Unit IV: Electronic Band Structure

Electronic band structure in solids, Electrons in periodic potentials, Bloch's Theorem, Kronig-Penney model, Nearly free electron model, Tight-binding model : density of states, examples of band structures. Fermi surfaces of metals and semiconductors.

Unit V: Transport properties

Motion of electrons in bands and the effective mass, currents in bands and holes, scattering of electrons in bands, Boltzmann equation and relaxation time, electrical conductivity of metals, thermoelectric effects, the Wiedemann-Franz Law.

Reference Books:

1. Solid State Physics : Hook and Hall : Hook and Hall
2. Introduction to Solid State Physics : Kittel
3. Solid State Physics : Ibach and Luth
4. Introduction to the Theory of Solids : H. M. Rosenberg
5. Solid State Physics : Blakemore
6. Solid State Physics : Ashcroft and Mermin

Semester II

Core Course **Quantum Mechanics II** **PHM-22C**

Unit I: Approximation methods for stationary systems

Time independent perturbation theory. Perturbation of non-degenerate states: first and second order perturbation. Perturbation of a harmonic oscillator. Perturbation of degenerate states, removal of degeneracy. Zeeman and Stark effects. Variational and WKB methods.

Unit II: Approximation methods for non-stationary systems

Schroedinger, Heisenberg and interaction pictures, Equations of Motion. Constant and harmonic perturbation. Discrete and continuous case, transition probability. Fermi golden rule. Adiabatic and sudden approximations.

Unit III: Scattering Theory

Scattering of a wave packet. The differential and total Cross section. The Born approximation. Partial waves and phase shifts. The Lippmann Schwinger equation. Definition and properties of S-matrix, T matrix. Optical theorem

Unit IV: Relativistic Quantum Mechanics

Klein-Gordon and Dirac equations, properties of Dirac matrices. Lorentz and CPT invariance of Dirac equation. Non-relativistic reduction of the Dirac equation. Central forces and the hydrogen atom.

Unit V: Solution to Dirac Equation

Free particle solution, hydrogen atom in dirac's theory, Dirac electron in constant magnetic field, Foldy-Wouthuysen transformation, Hole theory.

Reference Books :

1. Quantum Mechanics : Franz Schwabl
2. Quantum Mechanics : Eugen Merzbacher
3. Quantum Mechanics : N. Zettili
4. Quantum Mechanics : P. M. Mathews and K. Venkatesan
5. Principles of Quantum Mechanics : P. A. M. Dirac

Semester II

Core Course | **Electrodynamics** | **PHM-23C**

Unit I: Electrodynamics : Potential formulation and Conservations laws

Review of Maxwell's equations. Scalar and vector potentials. Gauge transformations. Coulomb and Lorentz Gauge, Conservation of energy and momentum, Poynting's theorem, Maxwell's Stress tensor.

Unit II: Wave equation: retarded solutions

Inhomogeneous wave equations, Green's functions for Poisson, Helmholtz and Wave equations. Retarded and Advanced solutions for Maxwell's equations. Jefimenko formulas for fields for charge and current distributions.

Unit III: Radiation by moving charge

Lienard-Wiechert Potentials. Electromagnetic field of a moving point charge. Radiation from an accelerated charge, Larmor's formula and Lienard's generalization (relativistic); Angular distribution of radiated power for linearly and circularly accelerated charges, Bremsstrahlung, Synchrotron, Cherenkov radiation (qualitative treatment only).

Unit IV: Radiation damping

Radiation reaction from energy conservation, Abraham-Lorentz formula, Self force.

Unit V: Relativistic Electrodynamics

Review of STR. Lorentz transformations. Electromagnetic field tensor, Transformation of electromagnetic fields, Covariant formulation of electrodynamics. Field due to a point charge in uniform motion, Energy-momentum tensor and the conservation laws for the electromagnetic field; the equation of motion of a charged particle in an electromagnetic field; Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.

Reference Books:

1. Classical Electrodynamics : J.D. Jackson,
2. Classical Theory of Fields : Landau & Lifshitz
3. Introduction to Electrodynamics: D. J. Griffiths
4. Foundations of Electromagnetic Theory : Reitz, Milford and Christy
5. Classical Charged Particle : Rohrlich

<u>Semester II</u>

Choice Based Elective **Mathematical Physics II** **PHM-21E**

Unit I: Vector spaces

Linear vector spaces : Vector spaces, inner product spaces, Cauchy sequence: eigenvalues, diagonalization and spectral theory , direct sum and product of matrices, Hilbert space : properties, function spaces, dual space, direct sum of function spaces, operators.

Unit II: Discrete groups

Discrete Groups : examples, multiplication table, conjugate elements and classes, subgroups, normal subgroups, factor groups, direct product of groups, isomorphism & homomorphism, group of symmetries of regular polygon, permutation groups,

Unit III: Representation of groups

Invariant subspaces and reducible representations, Schur's lemmas and the orthogonality theorem, characters of a representation, regular representation, symmetrized basis functions for irreducible representation, transfer and projection operators, direct product of representations, representations of a direct product group, examples

Unit IV: Continuous groups

Continuous groups : Topological groups and Lie groups, axial rotation group SO(2), 3-D rotation group SO(3), Lorentz group, Special Unitary group SU(2), generators of U(n) and SU(n), Lie algebra and representations of Lie group, Special Unitary group SU(3), examples

Unit V: Permutation groups

Permutation group, disjoint and non-disjoint cycles, transpositions, parity, generators, classes, character table, representations, partitioning of n, Young diagrams, Young tableau

Reference Books:

1. Elements of group theory for physicists, 4^{th} Ed., A W Joshi, New Age Int.
2. Group Theory by Abbas, Taylor & Francis
3. Mathematical methods for physicists, 6^{th} Ed., Arfken & Weber, Elsevier
4. Group Theory by Hamermesh
5. Mathematical Physics, by Sadri Hassani, II Ed., Springer

Semester II

Ability Enhancement course **Experimental Techniques** **PHM-21A**

Unit I: Basic Data processing

Recording and analysis of data, data uncertainty, Error: - accuracy and precision, computer-aided data acquisition

Unit II: Introduction to Vacuum

Fundamentals of Vacuum, Gas Flow Mechanism, Concept of Throughput and Pumping Speed, Various types of Pumps - Pressure Measurements gauges, valves, seals - Leak Detection techniques

Unit III: Thin Film deposition

Physical vapour deposition, thermal evaporation, e-beam evaporation, sputtering, pulsed laser deposition, molecular beam epitaxy, MOCVD.

Unit IV: Single Crystal growth

Bridgman-Stockbarger and Czochralski method, flux and hydrothermal method, purification of materials, zone refining.

Reference Books:

1. Vacuum Technology: Alexander Roth
2. The Growth of Single Crystals : R.A. Laudise
3. The Art & Science of Crystal Growth : J.J. Gilman.
4. Material Science and Engineering : V. Raghavan
5. Essentials of Crystallography : M.A. Wahab
6. Crystal growth for beginners : Ivan Markov
7. Physics of Crystal Growth: Alberto Pimpinelli and Jacques Villain

<u>Semester II</u>

Physics Practical **Lab II** **PHM-21L**

List of Experiments :

1. Study of radioactivity by using a G.M. tube to (i) Determine background radiation and (ii) Study absorption in air of β and γ radiation from ^{137}Cs and ^{60}Co sources.

2. Hall effect : Study of the dependence of Hall coefficient on temperature.

3. Determination of the magnetic susceptibility of $Mncl_2$ by Quincke's tube method.

4. Study of magnetoresistance of doped semiconductors.

5. Study of magnetic hysteresis in various ferromagnetic materials using a Hysterisis loop tracer .

6. Frank- Hertz experiment.

7. Determination of the dissociation energy of Iodine molecule.

8. Fourier analysis of sinusoidal, triangular and square waveforms.

9. Determination of the Curie temperature of ferroelectric materials.

10. Determination of the forbidden energy gap of semiconductors.

11. Determination of the e/m ratio of electrons by Thomson's method using a fine beam electron tube and Helmholtz coils.

12. Determination of the dielectric constants of amorphous and crystalline solids.

13. Determination of the Landé g factor of electrons using ESR.

14. Determination of ultrasonic velocity in liquids.

15. Study of the temperature dependence of resistivity of semiconductors by the 4-probe method.

16. Study of I-V characteristics, and determination of the fill-factor and efficiency of a solar photovoltaic cell.

17. Study of Zener and avalanche breakdown in P-N junction diodes as a function of Temperature.

Semester III

Core Course **Atomic & Molecular Physics** **PHM-31C**

Unit I: Basic Concepts

Review of Solution of Schroedinger's equation for Coulomb field and Hydrogen atom, dipole approximation, spectroscopic terms and selection rules, intensities of spectral lines.

Unit II: Interaction with Electromagnetic Field

Fine structure of Hydrogen like atoms: spin-orbit interaction, relativistic correction, Lamb shift. Interaction with external fields: Zeeman, Paschen-Back and Stark effects.

Unit III : Atomic Spectra

The LS-coupling approximation, J-J coupling, hyperfine structures. The central field approximation, Thomas Fermi-potential, alkali atom spectra, Na doublet.

Unit IV: Molecular Spectra

Born-Oppenheimer Approximation, Rotational, Vibrational, Rotational-Vibrational and Electronic spectra of Di-atomic molecules, Selection rules, Frank-Condon principle, Raman spectra, NMR, ESR.

Reference Books:

1. Physics of Atoms and Molecules : B.H. Bransden & C.J. Joachain
2. Elementary Atomic Structure : G.K. Woodgate
3. Introduction to Modem Physics : H.S. Mani & G.K. Mehta
4. Molecular Spectra : G. Herzberg
5. Fundamentals of Molecular Spectroscopy : C.N. Banwell

Semester III

Core Course **Nuclear & Particle Physics** **PHM-32C**

Unit I: Basic Nuclear Concepts

Angular momentum, Parity and symmetry, Magnetic dipole moment and electric quadrupole moment, Energy levels and mirror nuclei.

Unit II: Nuclear Forces

Characteristics of nuclear forces -Range and strength, Simple theory of two nucleon system - deuterons, Spin states of two nucleon system, Effect of Pauli's exclusion principle, Magnetic dipole moment and electric quadrupole moment of deuteron -The tensor forces.

Unit III : Energy deposition and Particle detection

Interaction of charged particles with matter. Stopping power and range. Detectors for energetic charged particles; Solid State or Semiconductor detector.

Unit IV: Particle Accelerators

Need for accelerator of charged particles, Classification of types of accelerators, Proton Synchrotron, Betatron; Alternating gradient accelerator, Colliding beam accelerator.

Unit V: Elementary particles

Classification and properties of elementary particles; Resonances ; Interactions and their mediating quanta, Conservation rules in fundamental interactions; Strangness and associated production, Isospin and its conservation. Parity and charge conjugation, Conservation of parity and its violation Idea of eight fold way and quarks.

Reference Books:

1. Nuclei and Particles : Segre
2. Nuclear Physics : Cohen
3. Nuclear Physics : Enge
4. Physics of Nuclei and Particles : Marmur and Sheldon
5. Introduction to Nuclear and Particle Physics : Das and Ferbel

Semester III

Core Course **Advanced Topics in Material Science** **PHM-33CM**

Unit I: Crystal structure, symmetry and electronic energy levels

Review of bonding in solids and electronic structure, link between valence electronic states and crystal symmetries, density of states for metals, semiconductors and insulators, dispersion of electron energy levels, van Hove singularities, energy bands, Fermi surfaces, De Haas - van Alphen effect.

Unit II: Experimental determination of electronic structure

X-ray and ultraviolet photoelectron spectroscopies and Auger electron spectroscopy. Chemical shift determination. Calculation of electronic energy levels and their dispersion, using angle-resolved photoemission spectra.

Unit III: Density Functional Theory

Extension of Central Field Approximation, Hohenberg-Kohn Theorems, statement and proof. Kohn Sham orbitals, pseudo potentials, the self-consistent field method for the calculation of ground state energies in DFT.

Unit IV: Crystal growth and defects

Kinetics of Crystal Growth: homogenous and heterogenous nucleation, diffusion and screw dislocation mechanism of crystal growth. Atomic imperfections in crystals- one, two and three dimensional imperfections, Schottky and Frenkel defects, Burger's vector and Burger's circuit, energy of dislocations, grain boundaries and surface reconstructions.

Reference Books:

1. Intro. To Solid State Physics: Chales Kittel
2. Solid State Physics : Ibach & Luth
3. Quantum Theory of Solids : Charles Kittel
4. Solid State Physics: Ashcroft and Mermin
5. Experimental Techniques of Surface Science : Woodruff and Delchar
6. Density Functional Theory: Kieron Burke.
7. Electronic Structure: Richard M. Martin
8. Crystal growth for beginners : Ivan Markov
9. Physics of Crystal Growth: Alberto Pimpinelli and Jacques Villain
10. Material Science and Engineering : V. Raghavan

Semester III

Core Course | **Laser Physics** | **PHM-33CL**

Unit I: Optical Resonators and Gaussian Beam

Brief review of matrix optics, Planar Mirror Resonators, Resonator Modes, Two- and Three-Dimensional Resonators, Spherical-Mirror Resonators, Ray confinement, Gaussian waves and its characteristics: The Gaussian beam, Transmission through optical component, Gaussian Modes, Resonance Frequencies, Hermite-Gaussian Modes, Finite Apertures and Diffraction Loss.

Unit II: Photons and Atoms

The Photon Optics theory of light in a resonator, Photon Polarization, Transmission and interference of photon, Photon time, Photon streams. Energy levels and Occupation of energy levels in thermal equilibrium, Interaction of single mode light with an atom, Spontaneous Emission, Transition Probabilities, Stimulated Emission and absorption, line shape function, Transition in presence of broadband light, Lineshape broadening: Homogeneous and Inhomogeneous Broadening. Lifetime broadening, Collision Broadening, Doppler Broadening.

Unit III : LASER Amplifiers

Theory of laser amplifiers, Gain and band width, Phase shift, Rate equations, pumping schemes, Common Laser amplifiers, Doped glass amplifiers, Amplifier Nonlinearity and stability saturation-saturated gain in homogeneously and inhomogeneously broadened media. Amplifier noise.

Unit IV: Lasers

Theory of laser oscillation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output, Mode selection, Common lasers; Selected characterises of common lasers, Pulsed lasers: Methods of pulsing lasers, Q-switching, Mode locking.

Reference Books:

1. Introduction to Laser Physics : K.Shimoda
2. Principles of Lasers : O. Svelto
3. Lasers- Theory and Applications : Thyagarajan and Ghatak
4. Fundamentals of Photonics: B.E.A. Saleh and M.C. Teich

Semester III

Core Course **Classical Field Theory** **PHM-33CT**

Unit I: Review of Classical Physics

Hamiltonians and Lagrangians. Legendre transforms and their properties. Euler-Lagrange equations. Principle of least action. (Functional calculus.) What is classical field theory? Group theory from invariances of classical equations. Newton's equations and the Galilean group. Maxwell's equations. Special Relativity and the Lorentz group. Vectors and tensors of the rotation and Lorentz groups.

Unit II: Basics of CFT

Systems with infinite degrees of freedom. Locality in space and time. Lagrangian densities for real and complex scalar fields. Euler-Lagrange (EL) equations. Functional calculus revisited. Hamiltonian density. The energy-momentum tensor. Finite-energy time-independent solutions -- classical vacua. Kinks in the Sine-Gordon and φ^4 theories. Green functions as singular solutions. Boundary conditions.

Unit III: Symmetries : Secret Symmetry and Local Symmetries

Discrete and continuous symmetries. Noether's theorem: the energy momentum tensor, the generalized angular momentum and the electromagnetic current. (Lie groups and Lie algebras. Representations of groups.) Global symmetries. Spontaneous breakdown of symmetry. Goldstone's theorem. (Coset spaces in group theory.) Abelian gauge fields. Covariant derivatives and minimal coupling. The abelian Higgs model. Vortex solutions (in type II superconductors). Topological conservation laws. The abelian Higgs mechanism.

Unit IV: The massless vector field

The Lagrangian density. Gauge invariance and the electromagnetic field strength. Maxwell's equations. Lorentz invariants of the field strength. The symmetrized energy-momentum tensor. The generalized angular momentum and the spin of the photon.

Unit V: Solitons and Instantons

Solitons as finite-energy solutions. Derrick's theorem. Getting around Derrick's theorem. Local symmetries and gauge fields. Abelian vortices. The Dirac monopole as a singular solution of Maxwell's equations. Dirac quantization. Instantons as finite action solutions to the EL equations.The 't Hooft solution. Nahm and Bogomolnyi equations from dimensional reduction.

Reference Books:

1. The Classical Theory of Fields : L. D. Landau and E. M. Lifshitz.
2. Classical Fields : M. Carmeli,
3. Electrodynamics and Classical Theory of Fields : A. O. Barut,
4. Aspects of Symmetry : S. Coleman,
5. Solitons and Instantons: R. Rajaraman

<u>Semester III</u>

Choice Based Elective **Characterization of Materials** **PHM-31E**

Unit I: Optical methods of structure determination

Optical microscopy, Raman spectroscopy, UV-Vis absorption spectroscopy, FTIR spectroscopy, Photoluminescence

Unit II: Determination of Surface Structure

Microscopy techniques: SEM, AFM, TEM, STM. Electron Diffraction techniques : Low Energy Electron Diffraction, Reflection High Energy Electron Diffraction.

Unit III: Surface analytical techniques for electronic structure

Auger electron spectroscopy, X-Ray photoelectron spectroscopy, SIMS, Rutherford backscattering

Unit IV: X-Ray Diffraction Studies

Diffraction phenomena as applied to Solid State problems, scattering and absorption of X-rays, neutrons and electrons. X-ray method for orienting crystals. Applications of XRD. Diffraction from regular and faulted closed packed structures. Broadening of diffraction spots due to defects. Line prifile analysis, crystal structure analysis, measurement of intensities of X-ray reflection.

Reference Books:

1. Experimental techniques of surface science : Woodruff and Delchar
2. Solid State Physics : Ashcroft and Mermin
3. Amorphous Materials : S.R.Elliot
4. Fundamentals of surfaces and thin film analysis : L.C.Feldman and J.W.Mayer
5. An introduction of X-ray crystallography : M.M.Wofson
6. Use of films in Physical investigations : J. C. Anderson
7. Rutherford backscattering Spectroscopy : W. K. Chu

Semester III

Choice Based Elective **Photonics** **PHM-32E**

Unit I: Polarization Optics

Polarization of Light, Optics of anisotropic media: The index ellipsoid, Birefringence, Polarization devices: Wave retarders, rotators and optical isolators. Magneto-Optic effect: Optical activity and Faraday effect

Unit II: Electro-optics and Acousto-optics

Pockels and Kerr Effect- Electro-optics of Anisotropic media, Phase and amplitude modulators, Beam Deflection and scanning devices, Photorefractive materials. Acousto-optics, Bragg diffraction and acousto-optic devices and their applications.

Unit III: Non-linear Optics and Optical Bistability

Non-linear optical media, second order non-linear optics- SHG, Three wave mixing. Third order non-linear optics, THG and self phase modulation. Four wave mixing and Optical Phase conjugation. Frequency conversion, Parametric Amplification and Oscillation. Self focusing of light. Bistable Systems, Principle of optical bistability, Bistable Optical devices, Optical logic and switching.

Unit IV: Photonic-Crystal Optics

Optics of Dielectric Layered Media: Matrix theory of multilayer optics, Bragg Grating. One-dimensional photonic Crystals - Bloch modes, dispersion relation and photonic band structure. Two- and three dimensional photonic crystals.

Reference Books:

1. Fundamentals of Photonics: B.E.A. Saleh and M.C. Teich
2. Photonics: Ralf Menzel
3. Quantum Electronics : A.Yariv
4. Nonlinear Optics : R.W. Boyd
5. Optics and Lasers : M.Young
6. Optical Electronics : A. Ghatak & K. Thyagarajan

Semester III

Choice Based Elective **General Relativity** **PHM-33E**

Unit I: Geometrical Basis

Vector and tensor fields, Affine connections, Metric tensor, Covariant derivative, Parallel transport Geodesic equation, Riemann curvature tensor. Symmetry properties of Riemann tensor. Bianchi identity. Ricci and Einstein tensor.

Unit II: Physics in Curved Spacetime

Equivalence Principle, Gravity as spacetime curvature, Weak gravitational field limit, Stress-energy tensor for a perfect fluid. Conservation equation for matter, Einstein equations (From Action Principle), Weak field limit of Einstein equations.

Unit III: Gravity in Simple Situations

Einstein equation in vacuum, Schwarzschild solution, Motion along a geodesic, Newtonian approximation, Gravitational redshift, Planetary motion and precession of the perihelion. Bending of light by a gravitating body.

Unit IV: Black Holes

Singularities in the Schwarzschild metric, Schwarzschild solutions in Kruskal-Szekeres coordinates. Gravitational collapse and black formation, Spherically symmetric collapse of dust, Reissner Nordstrom solution, Kerr solution.

Unit V: Cosmology

Cosmological principle; Robertson-Walker metric; Hubble's Law, Cosmological Redshift, Deceleration parameter, Distances, Cosmological fluid and its components, Matter conservation equation, Friedman Equation and Standard models, Closed, Flat and Open universe, Age of the universe.

Reference Books:

1. General Relativity : M.P.Hobson, G.P. Efstathiou and A.N.Lasenby
2. Gravitation and Cosmology : S.Weinberg
3. The Classical Theory of Fields: L.D.Landau and E.M.Lifshitz
4. Gravity: J.B.Hartle
5. Spacetime, Geometry and Gravitation : Pankaj Sharan

Semester III

Skill Enhancement Course | **Numerical Analysis And Programming** | **PHM-31A**

Unit I: Lab sessions

Sources of errors, propagation of errors in arithmetic operations, representation of numbers on computers, arithmetic of normalized floating point numbers, computer algorithm, Implementation of Numerical techniques using Fortran 2003/ANSI C.

Unit II: Solution of algebraic and transcendental equations

Chebyshev method, Steffensen method, Fixed point iteration, order of convergence, Singular Value Decompositions(SVD), eigenvalues and eigenvectors, Givens method and Householder method for symmetric matrices, QR Decompositional linear sparse systems, power method for finding extreme eigenvalues and eigenvectors; Maximization and minimization of functions.

Unit III: Interpolation and extrapolation

Lagrange's interpolation polynomial, Hermite Interpolation, Cubic spline interpolation, Fast Fourier Transform, Least square approximation, Approximation using orthogonal polynomials, Maximization for minimization of functions.

Unit IV : Differentiation and Integration

Differentiation based on Lagrange's Interpolation polynomial, two-point and three point formulae, Simpson's method, Romberg integration, Random number generator, Monte Carlo Integration; Gauss Quadrature: Legendre, Chebyshev, Hermite, Laguerre.

Unit V : Ordinary and partial differential equations

Ordinary differential equations, initial value problem, boundary value problem, Partial differential equations: parabolic, elliptic, hyperbolic; Finite Element Method(FEM)

Reference Books:

1. Numerical Analysis: C. F. Gerald, P. O. Wheatley
2. Numerical Analysis for Scientists and Engineers Theory and C Programs : Madhumangal Pal.
3. Fortran 95/2003 for Scientists and Engineers : Stephen J Chapman
4. Numerical Methods for Scientific and Engineering Computation : Jain, Iyengar and Jain
5. Numerical Analysis: Richard L Burden and J Douglas Faires
6. Computational Physics : J M Thijssen .
7. Numerical Recipes in C : The Art of Scientific Computing : Press, Teukolsky, Velleling and Flannery

Semester III

Physics Practical **Lab III** **PHM-31L**

List of Experiments :

1. Study of characteristics of a single mode optical fiber and determination of transmission losses.

2. Study of characteristics of a multi mode optical fiber and determination of transmission losses.

3. Determination of the (i) Rydberg constant using an optical grating and Hg lamp; (ii) H_2 and He spectral wavelengths.

4. Study of diffraction of light from a laser light source through a single slit using a photo-cell.

5. Determination of the specific charge of the electron by the Millikan's oil drop method.

6. Study of the Zeeman effect in Hg light spectra.

7. Study of electron diffraction upon transmission through a thin graphite film.

8. Study of diffraction and interference in microwaves.

9. Study of the characteristics and efficiency of a PEM fuel cell system.

10. Determination of the Curie temperature of ferromagnetic materials.

11. Study of a Fabry-Perot interferometer.

12. Study of radioactivity by using a G.M. tube to : (i) determine the range of α, β particles in air and (ii) absorption of γ radiation in various materials.

13. Study of energy storage using a solar thermal training system.

14. Study of solar photovoltaic cells (i) singly and (ii) in series and parallel configurations.

<u>Semester IV</u>

Core Course | **Statistical Mechanics** | **PHM-41C**

Unit I: Statistical basis of thermodynamics

The macroscopic and the microscopic states, phase space, trajectories and density of states, Liouville's theorem, ensemble theory, the principle of maximum entropy, contact between statistical mechanics and thermodynamics, classical ideal gas, entropy of mixing and Gibb's paradox

Unit II: Canonical and grand-canonical ensembles

Classical canonical ensemble, partition function, calculation of statistical quantities, Energy fluctuations. The grand canonical ensemble, particle number fluctuation. Entropy in grand canonical ensemble, thermodynamic potentials.

Unit III : Quantum Statistical Mechanics

Postulates of quantum statistical mechanics, density matrix, statistics of ensembles. Statistics of indistinguishable particles, Maxwell-Boltzmann, Fermi-Dirac and Bose Einstein statistics, properties of ideal Bose and Fermi gases, Bose-Einstein condensation.

Unit IV: Phase transitions

Type of phase transitions, first and second order phase transitions. Ising model, mean-field theories of the Ising model in two and three dimensions, exact solution in one dimension. Connection of Ising model to lattice gas and binary alloy models. Landau theory of phase transition, Landau free energy for second and first order transitions, critical exponents and universality classes.

Reference Books:

1. Statistical and Thermal Physics : F. Reif
2. Statistical Mechanics : K. Huang
3. Statistical Mechanics : R. K. Pathria
4. Statistical Mechanics: R. Kubo
5. Statistical Physics : Landau and Lifshitz
6. Thermodynamics and Statistical Mechanics : Greiner, Neise and Stocker
7. Statistical Physics : F. Mandl

Semester IV

Core Course **Condensed Matter Physics II** **PHM-42C**

Unit I: Interacting Electrons in Solids

Review of free electron theory, nearly free electron approximation, tight-binding model, LCAO approximation, Wannier functions, Hartree-Fock approximation, Dielectric constant of metals and insulators.

Unit II: Optical Properties

Electronic, interband and intraband transitions, relation between optical properties and band structure, reflectance, diffraction, dispersion, photoluminescence, electroluminescence, optical constants, Kramers-kronig relations, polarons, excitons, plasmons.

Unit III : Magnetism

Diamagnetism (including Landau diamagnetism) and Paramagnetism including van Vleck and Langevin paramagnetism), Exchange interaction of free electrons, Band model of Ferromagnetism, superexchange, double exchange, Hubbard model, Antiferromagnetism, Neel temperature, spin-waves, 2D electron gas in a magnetic field :Quantum Hall Effect. Landau levels. Degeneracy. Fractional quantum Hall effect.

Unit IV: Superconductivity and Superfluidity

Fundamental phenomena of superconductivity, Meissner effect, London equation, Type I and type II superconductors. Ginzburg-Landau Theory, Coopers pairing and BCS theory. BCS wave functions, Josephson Effect, SQUIDS. Weakly interacting Bose gas, Superfluidity.

Reference Books:

1. Introduction to Solid State Theory : O. Madelung
2. Solid State Physics : Ibach and Luth
3. Solid State Physics : Ashcroft and Mermin
4. Introduction to Solid State Physics : C. Kittel
5. Quantum Theory of Solid : C. Kittel
6. Many-Particle Physics (Physics of Solids and Liquids) : G.D. Mahan

Semester IV

Core Course **Physics & Technology of Semiconductor Devices** **PHM-43CM**

Unit I: MESFET and Related Devices

Metal-semiconductor contacts; Basic Characteristics, Schottky Barrier, Ohmic Metal Semiconductor Contact, Current Transport process, Determination of Barrier Height, MESFET; Device Structures, Principles of Operations, Current Voltage Characteristics, High Frequency Performance, MODFET or HEMT; fundamentals, , Current -Voltage Characteristics, Cut off Frequency.

Unit II: MOSFET and Related Devices

MOS Diode; SiO_2-Si MOS Diode, Charge Coupled Device (CCD), MOSFET Fundamentals; Basic Characteristics, Types of MOSFET, Threshold Voltage Control, MOSFET Scaling; CMOS and BiCMOS; MOS Memory Structures.

Unit III: Quantum Effect and Photonic Devices

Quantum-Effect Devices; Resonant Tunneling Diode, Unipolar Resonant Tunnelling Transistor, Semiconductor Laser; Semiconductor Materials, population Inversion at a junction, Emission spectra for p-n junction Lasers, Basic Laser Structure, Photodetector; Photoconductor, Solar Cell; p-n junction Solar cell, conversion Efficiency.

Unit IV: Film Formation and Epitaxial Growth

Thermal Oxidation; Dielectric Deposition; Thin Films Deposition Techniques: Thermal evaporation, Sputtering, Chemical Vapour Deposition(CVD), LPCVD, Epitaxial Growth Techniques: Vapour phase Epitaxy, Molecular Beam Epitaxy (Elementary description).

Unit V: Lithography, Etching and Diffusion of impurities

Optical Lithography; Exposure Tools, Masks, Photoresist, Electron Beam Lithography (Elementary description) ,Wet Chemical Etching, Dry Etching, Reactive Plasma Etching techniques and Equipment, Basic Diffusion Process: Diffusion Equations, Doping of Semiconductor.

Reference Books:

1. Semiconductor Devices Physics and Technology : S.M. Sze
2. Introduction to Semiconductor Devices: S.M. Tyagi
3. Physics of Semiconductor Devices : S.M. Sze,
4. Solid State Electronics : Ben G. Streetman
5. Material Science by Engineers : James F. Shackelford
6. The Physics of Semiconductor Devices : D.A. Eraser, Oxford Physics Series (1986)
7. Thin Film Phenomena : K.L. Chopra.
8. Semiconductor Physics and Devices : S.S.Islam

Semester IV

Core Course **Quantum Optics** **PHM-43CL**

Unit I: Quantum Theory of Radiation

Quantization of free electromagnetic fields, Fock states, Lamb shift, quantum beats, concept of photons, coherent and squeezed states of lights, quantum distribution theory and partially coherent radiation.

Unit II: Coherence and Light-matter interaction

First and second-order coherence, HBT effect, photon bunching and anti bunching, Poissonian and sub-poissonian light, photon counting and photon statistics, Atom- field interaction : semi classical theory and quantum theory, coherent trapping, electromagnetically induced transparency and lasing without inversion.

Unit III: Quantum theory of damping

Density operator method and Langevin approach, quantum theory of laser, squeezing of light in nonlinear optical process, Atom optics : mechanical effects of light, atomic interferometry, quantum noise in an atomic interferometer, limits to laser cooling.

Unit IV: Measurements in Correlated Quantum Systems

Introductory ideas on EPR paradox, Bells inequality, QND measurements and two photon interferometry

Reference Books:

1. Elements of Quantum Optics : Meystre and Sergent
2. Quantum optics : M.O. Scully and M.S. Zubairy
3. Optical coherence and quantum optics : Mandel and Wolf
4. Laser physics : Sargent, Scully and Lambs

Semester IV

Core Course **Particle Physics** **PHM-43CT**

Unit I: Invariance Principles and Symmetries

Charge conjugation, time reversal and parity , CPT theorem, Quark model and color and flavour quantum numbers, Weak isospin and hypercharge.

Unit II: Introduction to Gauge Theories

Abelian and non-abelian gauge theories, Spontaneous symmetry breaking, Goldstone theorem, Higgs phenomenon

Unit III: Standard Model

Historical introduction to Fermi theory and current algebra, Weinberg-Salam model, Basic Lagrangian, neutral current, GIM mechanism, KM matrix and CP violation.

Unit IV: Strong Interactions

Basic Lagrangian of QCD and its symmetries, Asymptotic freedom, Deep inelastic scattering

Unit V: Some Special topics

Anamolies, supersymmetry, string theory.

Reference Books:

1. Introduction to High Energy Physics : Perkins
2. Gauge Theory of Weak Interactions : Greiner & Muller
3. Gauge Theory and Particle Physics : Cheng Lee

<u>Semester IV</u>

Choice Based Elective **Physics of Novel Material** **PHM-41E**

Unit I: Quantum Well Structures

Electron confinement in infinitely deep square well, confinement in one and two dimensional well, idea of a quantum well structure, quantum dots, quantum wires

Unit II: Carbon nanotubes

Carbon nanotubes and other carbon materials, bonding between carbon atoms, single and multiwalled nanotube growth and characterization, electronic structure, crsytal structure, junctions and defects of nanotubes. Electronic structure, transport, optical properties, thermal and mechanical properties of nanotubes. Electron spectroscopy and scanning probe microscopy of nanotubes. Applications of carbon nanotubes.

Unit III : Non-carbon nanostructures

Semiconductor heterostructures, synthesis of nanomaterials using chemical techniques.

Unit IV: MEMS & NEMS

MEMS (microelectromechanical systems) and NEMS (nanoelectromechanical systems), nanomachines and applications.

Reference Books:

1. Quantum Dot Heterostructures : D. Bimberg, M.Grundman, N.N. Ledentsov
2. Carbon Nanotubes: Synthesis,Structure, Properties and Applications : M.S. Dresselhaus, G. Dresselhaus, Ph.Avouris
3. Electronics in Non-crystalline materials : Mott and Davis
4. Physics of Amorphous materials : Elliot
5. Superconductivity : A. V. Narlikar
6. Introduction to Solid State Theory : O. Madelung

Semester IV

Choice Based Elective **Laser Spectroscopy** **PHM-42E**

Unit I: Laser Spectroscopic Instrumentation

Monochromators. Interferometers. Laser detectors: Photocells, Photomultipliers, Photon Counters, Optical multichannel analyzer, Boxcar averager. Laser powers/Energy meters.

Unit II: Doppler-limited Spectroscopy with Laser

Advantages of Lasers in spectroscopy. Doppler-limited absorption spectroscopy: Excitation spectroscopy, Optoaccoustic spectroscopy, Intracavity absorption. Optogalvanic spectroscopy, Ionization spectroscopy. Laser induced fluorescence. Stepwise excitation. Spectroscopy of Rydberg states. Multiphoton spectroscopy.

Unit III: Nonlinear and Time resolved Spectroscopy

Doppler-free techniques in spectroscopy. Laser Raman spectroscopy: Stimulated Raman Scattering, Coherent Anti-stokes Raman spectroscopy(CARS), Experimental tehniques of Laser Raman spectroscopy, Applications of Laser Raman spectroscopy, Non-linear Raman spectroscopy. Time resolved Laser spectroscopy: Lifetime measurements with lasers.

Unit IV: Recent trends in Laser spectroscopy

Spectroscopy of single ions, Spectral resolution within the natural linewidth. Absolute frequency measurements and Optical frequency standards.

Reference Books:

1. Laser Spectroscopy : W. Demtroeder
2. Atomic and Laser Spectroscopy : A.Corney
3. Molecular and Laser Spectroscopy : Zu-Geng Wang, Hui-Rong Xia

Semester IV

Choice Based Elective **Quantum Field Theory** **PHM-43E**

Unit I: Canonical Quantization

Canonical quantization of neutral scalar, Charged scalar, spin 1/2 and massive spin-1 fields, Fock space and observables. Field commutation, anti-commutation relations.

Unit II: Interacting Fields

Interaction picture. Normal product. Wick's theorem. Feynman propagator. S-matrix. Feynman rules and diagrams

Unit III: Quantum Electrodynamics

Quantization of electromagnetic field. Gupta- Bleuler condition. Indefinite metric. Feynman diagrams of QED.

Unit IV: Scattering (tree level) in QED

Tree level calculations of Moller, Bhabha, Compton and Scattering in external field

Unit V: Some Special topics

1-loop corrections and renormalization. RG equations.

Reference Books:

1. Introduction to Relative Quantum Field Theory : S.S. Schwebber
2. Introduction to Quantized Field Theory : Bogoliubov & Shirkov
3. Relativistic Quantum Mechanics : Bjorken & Drell
4. Quantum Field Theory : Bjorken & Drell
5. Quantum Field Theory : Itzyksen & Zuber

Semester IV

Core Course **Project** **PHM-44C**

Guidelines for Project in M.Sc. Course :

1. Projects would be allotted to III Semester students which have to be carried out and completed in Semester IV.

2. The students will have an option to select the project in their field of interest. The projects shall be undertaken under the supervision of faculty within the department of physics or any other department / center of the university. In case the student wishes to work with a scientist in an institute outside Jamia Millia Islamia, she/he shall need to have a co-supervisor within the dept. of physics, Jamia Millia Islamia.

3. The project will comprise of the following:

- Survey and study of background literature material
- Experimental/analytical/computational research work, Collection of data, analysis of results.
- A dissertation or project report to be submitted by the end of the 4th semester.

4. The final evaluation of the completed project work will be based upon the work done, the submitted project report and an oral presentation.