Syllabus for M.Sc. Course in Physics

2015

Department of Physics

DIAMOND HARBOUR WOMEN`S UNIVERSITY

Two – year, 4 – Semester PG Course in Physics:
Grand Total Marks - 1000

(First Year) First Semester:

Paper	Subject	Marks in Semester Exam.	Marks in Midterm Evaluatiion / Sessional	Periods/Week
PHY/Th/101	Mathematical Methods	50		3
PHY/Th/102	Classsical Mechanics	50		3
PHY/Th/103	Electrodynamics	50		3
PHY/Th/104	Quantum Mechanics - I	50		3
PHY/LG/101	General Lab.-I*			12
Total		200		
***Examination for General Lab.-I, Carrying 100 marks will be held at the end of Second Semester**				

(First Year) Second Semester:

Paper	Subject	Marks in Semester Exam.	Marks in Midterm Evaluation/ Sessional	Periods/Week
PHY/Th/201	Quantum Mechanics- II	50		3
PHY/Th/202	Statistical Mechanics	50		3
PHY/Th/203	General Electronics	50		3
PHY/LG/202	Numerical Methods & Computer Programing (L)	50		3

PHY/LG/201 (/101-Contd.)	General Lab.-I*	100		12
Total		300		

(Second Year) Third Semester:

Paper	Subject	Marks in Semester Exam.	Marks in Midterm Evaluation/ Sessional	Periods/Week
PHY/Th/301	Condensed Matter Physics	50		3
PHY/Th/302	Nuclear & Particle Physics	50		3
PHY/Th/303	Atomic & Molecular Physics	50		3
PHY/ThE/304	Elective-I (Theory)**	50		3
PHY/LG/305	General Lab. - II	50		12
Total		250		
****From the list of Electives some will be offered. Students are free to choose one from those which will be offered.**				

(Second Year) Fourth Semester:

Paper	Subject	Marks in Semester Exam.	Marks in Midterm Evaluation/ Sessional	Periods/Week
PHY/Th/401	Advanced Theory***	50		3
PHY/LA/404	Advanced Lab***	50		12
PHY/ThE/402	Elective-IIA (Theory)#	50		3
PHY/ThE/403	Elective –IIB (Theory)#	50		3

XIPHY/VS/405	Seminar/Grand Viva	50		
Total		250		
***** From the list of Advanced subjects students should choose one (for both theory and Lab.) # From the list of Electives some will be offered. Students are free to choose two from those which will be offered.**				

*****Advanced Subjects: (Paper: PHY/Th/401 and PHY/LA/404)**

1. Advanced Electronics
2. Advanced Condensed Matter Physics

#Elective Subjects: (Paper: PHY/ThE/304,402,403)

1. Quantum Field Theory (Elective)
2. High Energy Physics (Elective)
3. Non-linear Dynamics (Elective)
4. Astrophysics (Elective)
5. Nuclear Physics (Elective)
6. Low Dimensional Structures and Quantum Well Devices (Elective)

M.Sc. Course in Physics
P.G. I - First Semester
Paper: PHY/Th/101(Mathematical Methods)

1. Vector space and matrices (7)
Vector space: Axiomatic definition, linear independence, bases, Gram-Schmidt orthogonalisation. Matrices: Introduction as representation of linear transformations; Eigenvalues and eigenvectors; Commuting matrices with degenerate eigenvalues; Orthonormality of eigenvectors.

2. Complex analysis (13)
Complex numbers, triangular inequalities, Schwarz inequality. Function of a complex variable: limit and continuity; Differentiation, Cauchy-Riemann equations and their applications; Analytic and harmonic function; Classification of singularities, Branch point and branch cut; Complex integrals, Cauchy's theorem and its converse, Cauchy's Integral Formula; Taylor and Laurent expansion; Residue theorem and evaluation of some typical real integrals using this theorem.

3. Theory of second order linear homogeneous differential equations (6)
Singular points — regular and irregular singular points; Frobenius method; Fuch's theorem; Linear independence of solutions — Wronskian, second solution. Sturm-Liouville theory; Hermitian operators; Completeness.

4. Inhomogeneous differential equations (3)
Green's functions

5. Special functions (3)
Basic properties (recurrence and orthogonality relations, series expansion) of Bessel, Legendre, Hermite and Laguerre functions.

6. Integral transforms (3)

Fourier and Laplace transforms and their inverse transforms; Transform of derivative and integral of a function; Solution of differential equations using integral transforms.
Tutorials (10)

Books:
1. J. Matthews and R. Walker, Mathematical Methods for Physics.
2. G. B. Arfken and H. J. Weber, Mathematical Methods for Physics.
3. R. Courant and D. Hilbert, Mathematical Methods for Physics, Vols I and II.
4. P.K. Chattopadhyay, Mathematical Physics.

M.Sc. Course in Physics
P.G. I - First Semester
Paper: PHY/Th/102(Classical Mechanics)

1. Lagrangian dynamics (5)
Some specific applications of Lagarange's equation; small oscillations, normal modes and frequencies.

2. Hamilton's principle (6)
Calculus of variations; Hamilton's principle; Lagrange's equation from Hamilton's principle; Principle of least action. Aaaaaaaalegendre transormation and Hamilton's equations of motion.

3. Canonical transformations (4)
Generating functions and examples of canonical transformations; Poisson brackets.

4. Hamilton-Jacobi theory (4)
The Hamilton Jacobi equation for Hamilton's principle function; The harmonic oscillator problem; Hamilton's characteristic function; Action angle variables.

5. Rigid bodies (8)
Independent coordinates; orthogonal transformations and rotations (finite and infinitesimal); Euler's theorem, Euler angles; Inertia tensor and principal axis system; Euler's equations; Heavy symmetrical top with precession and nutation.

6. Special theory of relativity (10)
Lorentz transformations; 4-vectors, Tensors, Transformation properties, Metric tensor, Raising and lowering of indices, Contraction, Symmetric and antisymmetric tensors; 4-dimensional velocity and acceleration; 4-momentum and 4-force; Covariant equations of motion; Relativis-

tic kinematics (decay and elastic scattering); Lagrangian and Hamiltonian of a relativistic particle.

Tutorial (8)

BOOKS:

1. H. Goldstein, C. Poole and J. Safko, Classical Mechanics.
2. N.C. Rana and P.S. Joag, Classical Mechanics.
3. A.K. Raychaudhuri, Classical Mechanics.
4. L.D. Landau and E.M. Lifschitz, Course on Theoretical Physics Vol. 1 : Mechanics.

M.Sc. Course in Physics

P.G.I - First Semester

Paper: PHY/Th/103(Electrodynamics)

1. Electrostatics and Magnetostatics (6)

Boundary-Value Problems in Electrostatics. Neumann and Dirichlet problems.
Formal solutions using Green's function. Scalar and vector potentials; Multipole expansion of (i) scalar potential and energy due to a static charge distribution (ii) vector potential due to a stationary current distribution.Electrostatic and magnetostatic energy. Poynting's theorem.

2. Maxwell Equations (3)

Maxwell Equations, Macroscopic Electromagnetism. Electrodynamics. Conservation laws, Poynting's theorem.

3. Electromagnetic waves (6)

Plane Electromagnetic Waves and Wave Propagation. Effects of earth's magnetic field on the Propagation through ionosphere. Polarization. Reflection - Transmission - Total internal reflection. Waves in conducting medium. TE - TM - TEM waves ; Waveguides. Matching and attenuation, Excitation of modes, Resonant Cavity.

4. Moving charges (4)

Scalar and Vector Potential. Coulomb and Lorentz gauge. Retarded potentials. The Liennard-Wiechart potential. Time dependent Green's function.

5. Radiation (6)

Radiation. Electric and magnetic dipole radiation. Radiation from moving charges.
Linear antenna. Antenna Arrays,Cerenkov radiation.

6. Lagrangian formulation Relativistic electrodynamics (10)

Idea of a classical field as a generalised coordinate. Euler-Lagrange equation for the field from the

Lagrangian density. The field momentum and the Hamiltonian density. Poisson brackets for the fields. Equation of motion in an electromagnetic field; Electromagnetic field tensor, covariance of Maxwells equations; Maxwell's equations as equations of motion; Lorentz transformation law for the electro-magnetic fields and the fields due to a point charge in uniform motion; Field invariants; Covariance of Lorentz force equation and the equation of motion of a charged particle in an electromagnetic field; The eneralised momentum; Energy-momentum tensor and the conservation laws for the electromagnetic field; Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.

Tutorial (10).

BOOKS:

1. J.D. Jackson, Classical Electrodynamics.
2. W.K.H. Panofsky and M. Phillips, Classical Electromagnetism.
3. D.J. Griffiths, Introduction to Electrodynamics.
4. L. D. Landau and E. M. Lifschitz, Course on Theoretical Physics Vol. 2 : Classical Theory of Fields.

M.Sc. Course in Physics
P.G.I - First Semester
Paper: PHY/Th/104(Quantum Mechanics I)

1. Recapitulation of Basic Concepts (6)

Wave packet: Gaussian wave packet; Fourier transform; Spreading of a wave packet.
Coordinate and Momentum representations; x and p in these representations.
Eigenvalues and eigenfunctions: Momentum and parity operators; Commutativity and simultaneous eigenfunctions; Complete set of eigenfunctions; expansion of wave function in terms of a complete set. One-dimensional problems: Potential well and potential barrier. Reflection and transmission coefficients.

2. Operator method in Quantum Mechanics (5)

Formulation of Quantum Mechanics in vector space language. Uncertainty principle for two arbitrary operators. Linear harmonic oscillator by ladder operator formalism.

3. Quantum theory of measurement and time evolution (3)

Double Stern-Gerlach experiment for spin- 1/2 system; Schrodinger, Heisenberg and interaction pictures.

4. Three-dimensional problems (4)

Three dimensional problems in Cartesian and spherical polar coordinates; hydrogen atom.

5. Angular momentum (5)
Angular momentum algebra; Raising and lowering operators; Matrix representation for j = 1/2, j = 1; Spin; Addition of two angular momenta — Clebsch-Gordan coefficients.

6. Approximation Methods (12)
Time independent perturbation theory: First and second order corrections to the energy eigenvalues;First order correction to the eigenvector; Degenerate perturbation theory; Application to one-electron system – Relativistic mass correction, Spin-orbit coupling (L-S and j-j), Zeeman effect and Stark effect.Variational method: He atom as example; First order Perturbation; Exchange degeneracy; Ritz prin-ciple for excited states for Helium atom.WKB approximation.

Tutorial (10)

BOOKS:

1. D.J. Griffiths, Introduction to Quantum Mechanics.
2. J.J. Sakurai, Modern Quantum Mechanics.
3. L.I Schiff, Quantum Mechanics.
4. R. Shankar, Principles of Quantum Mechanics.

M.Sc. Course in Physics
P.G.I - First Semester
Paper: PHY/LG/101(General Lab. I) & PHY/LG/201 (General Lab. I)

1. Hall effect.
2. P-N junction characteristics.
3. R-C coupled amplifier.
4. Band gap by 4 probe method.
5. Fabry - Perot interferometer.
6. Characteristics of operational amplifier.
7. Measurement of Planck's constant.
8. Characteristics of Solar cell.
9. Determination of Rydberg const. / Frank –Hertz expt.
10. Ultrasonic interferometer.
11. Experiment using IC 555 Clock Pulse Generator, Ripple Counter Synchronous counter using J-K Flip-Flops, Decoder, Seven segment display, Monolithic decade counter

M.Sc. Course in Physics
P.G. I - Second Semester
Paper: PHY/Th/201(Quantum Mechanics II)

1. Time-dependent Perturbation Theory (5)
Time dependent perturbation theory, interaction picture; Constant and harmonic perturbations — Fermi's Golden rule; Sudden and adiabatic approximations.Two level systems, Rabi oscillation.

2. Scattering theory (10)
Laboratory and centre of mass frames, differential and total scattering cross-sections, scattering amplitude; Scattering by spherically symmetric potentials; Born approximation. Partial wave analysis and phase shifts; Ramsauer-Townsend effect; Relation between sign of phase shift and attractive or repulsive nature of the potential; Scattering by a rigid sphere and square well; Coulomb scattering;Formal theory of scattering — Green's function in scattering theory; Lippman-Schwinger equation.

3. Symmetries in quantum mechanics (8)
Conservation laws and degeneracy associated with symmetries; Continuous symmetries — space and time translations, rotations; Rotation group, homomorphism between SO(3) and SU(2); Explicit matrix representation of generators for j = 1/2 and j = 1; Rotation matrices; Irreducible

spherical tensor operators, Wigner-Eckart theorem; Discrete symmetries — parity and time reversal.

4. Identical Particles (3):
Meaning of identity and consequences; Symmetric and antisymmetric wavefunctions; Slater determinant; Symmetric and antisymmetric spin wavefunctions of two identical particles; Collisions of identical particles.

5. Relativistic Quantum Mechanics (9):
Klein-Gordon equation, Feynman-Stuckelberg interpretation of negative energy states and concept of antiparticles; Dirac equation, covariant form, adjoint equation; Plane wave solution and omentum space spinors; Spin and magnetic moment of the electron; Non-relativistic reduction; Helicity and chirality; Properties of γ matrices; Charge conjugation; Normalisation and ompleteness of spinors.

Tutorial: (10)

BOOKS:

1. D.J. Griffiths, Introduction to Quantum Mechanics.
2. J.J. Sakurai, Modern Quantum Mechanics.
3. L.I Schiff, Quantum Mechanics.
4. R. Shankar, Principles of Quantum Mechanics.

M.Sc. Course in Physics
P.G.I - Second Semester
Paper: PHY/Th/202 (Statistical Mechanics)

1. Review of introductory ideas: Specification of micro and macro states of a system; phase space; counting of number of microstates in phase space. (2)

2. Statistical ensemble, postulate of equal apriori probability, Liouville’s theorem, ergodic hypothesis. (3)

3. Micro canonical ensemble: Thermal interaction between systems in equilibrium, temperature, heat reservoirs, sharpness of probability distribution, application.(2)

4. Canonical ensemble: equilibrium between a system and a heat reservoir, distribution function, partition function, calculation of thermodynamic quantities, Gibb’s paradox.(8)

5. Grand canonical ensemble: Equilibrium between a system and a heat reservoir, distribution function, partition function, calculation of thermodynamic quantities. (7)

6. Formulation of Quantum Statistics: Quantum-mechanical ensemble theory, the density matrix, Quantum Liouville's theorem, Statistics of the various ensembles (Calculation of density matrices), density matrices for i) one election in a magnetic field ii) particle in box. (8)

7. BE and FD distribution, Thermodynamic behaviour of an ideal Bose gas, Bose- Einstein condensation, Thermodynamic behaviour of an ideal Fermi gas, statistical equilibrium of white dwarf stars. (7)

Tutorial: (8)

Books

1. F. Reif , Fundamentals of Statistical and Thermal physics, Mc Graw- Hill, New York
2. R .K. Pathria and Panl D. Beale, Statistical Mechanics, Elsevier (B.H)
3. K. Huang, Statistical Physics

M.Sc. Course in Physics

P.G.I - Second Semester

Paper: PHY/Th/203(General Electronics)

Electronic Devices and Circuits:

Devices

1: Brief review of p-n junction, p-i-n diode, p-n-p-n structures. Shockley diode, Thyristor, Diac, Triac, UJT, - Principle of operation and uses in simple circuits. (3)

Circuits

2: Network analysis using Laplace and Fourier Transforms. Concept of impedance function, poles and zeros, time domain behavior from pole zero plot. Concept of transfer function.(6)

3: Analysis of large signal amplifier, distortion in amplifiers, Tuned and Wideband amplifiers, Feedback amplifiers.(4)

4: Review of Amplitude and Frequency modulation. Power relation, detection, PLL, AVC, Principle of operation of Super het .receiver.(5)

5. Brief review of basic OPAMP applications. Active filters, Non-linear circuits, Series regulation of power supply using OPAMP, Switched mode Power Supply.(7)

6: Brief review of logic gates, Multivibrators, Flip flops ,Counters: Ripple, synchronous, ring, monolithic decade. Three stage register. Memories: ROM, EPROM, RAM, TTL Memory, Hexadecimal address, A/D and D/A converter.(5)

7: Microprocessor architecture and its operation, 8085/8086family, Assembly language programming, Interfacing, I/O port, peripheral subsystem, programmed I/O, interrupt controlled I/O, data acquisition system. (5)

Tutorial: (10)

Books:

1. Solid State Electronic Devices – B.G. Streetman and S.K.Banerjee
2. Fundamentals of Solid State Electronics – C.T.Sah
3. Network and Synthesis – D. Roychoudhury
4. Circuit Theory : Analysis and Synthesis – A. Chakraborty
5. Electronics Principle – A.P.Malvino
6. Op-Amp and Linear Integrated Circuits – R. Gayakawad
7. Digital Computer Electronics – A.P.Malvino
8. Integrated Electronics – Millman ands Halkais
9. Microprocessor Architecture , Programming and Applications – R.S. Gaonkar

M.Sc. Course in Physics

P.G. I - Second Semester

Paper: PHY/LG/202(Numerical Methods & Computer Programming)

1. Plotting of functions and data.

2. Numerical methods for (i) finding roots of equation (bisection and Newton-Raphson), (ii) integration (trapezoidal rule, Simpson's one-third rule), (iii) linear regression, (iv) solving first order differential equation (Euler method, Runge-Kutta method), (v) interpolation.

3. Generation of random number

4. Revision of numerical methods for integration, finding roots of equation, solving simultaneous linear differential equations, least squares fitting, interpolation, solving differential equations (Euler method).

BOOKS:

1. V. Rajaraman, Computer Oriented Numerical Methods.
2. W.H. Press et.al., Numerical Recipes.

M.Sc. Course in Physics
PG-II – Third Semester
Paper: PHY/LG/315 (General Lab. II)

1) e/m Experiment.
2) Electron Spin Resonance Spectrometer.
3) Lattice Dynamics.

4) Transmission line Characteristics.
5) Michelson Interferomet

M.Sc. Course in Physics
P.G.II - Third Semester
Paper: PHY/Th/301(Condensed Matter Physics)

1) **Crystallography:** Review of preliminary ideas, Bravais lattice and primitive vectors, primitive unit cell, Wigner Seitz cell, Reciprocal lattice, Brillouin Zone, Bragg and Laue formulation of X-ray diffraction, geometrical interpretation of Bragg's law, atomic and crystal structure factor, simple crystal structure – Diamond, Zinc blende, NaCl, CsCl etc, structure factor calculation. (5)

2) Lattice dynamics: Phonon and lattice vibrations, harmonic approximation, adiabatic approximation, vibrations of linear monatomic and diatomic lattices, normal modes and phonon lattice specific heat capacity, Debye model of specific heat capacity.(5)

3) Band theory of solids: Bloch equation, empty band, nearly free electron theory, band gap, number of states in a band, tight binding approximation, effective mass of an electron in a band, concept of holes, classification of metal, semiconductor and insulator, topology of Fermi surface, cyclotron resonance de Haas-Van Alphen effect.(5)

4) Magnetic properties of solids: Quantum theory of paramagnetism, spin paramagnetism, Pauli theory, Heissenberg's theory of ferromagnetism, antiferromagnetism.(5)

5) Magnetic resonances: Nuclear magnetic resonance, Bloch equation, longitudinal and transverse relaxation time, hyperfine field, electron spin resonance.(6)

6) Imperfections in solids: Frenkel and Schottky defects, defects in crystal growth, colour centres and photoconductivity, luminescence , alloys – order- disorder plenomena, Brag – Williams theory. (5)

7) Superconductivity: Phenomenological description of superconductivity, critical temperature, Meissner effect, magnetic propertice, critical field, London equation, microscopic theory, qualitative features.(6)

Tutorial: (8)

Books

1) Introduction to Solid State Physics, Charles Kittel, John Wiley & Sons.
2) Solid State Physics, Neil W.Asheroft and N.David Mermin, Harcourt Asia PTF Ltd.

M.Sc. Course in Physics

P.G. II – Third Semester

Paper: PHY/Th/302 (Nuclear and Particle physics - General)

1. General properties of Nuclei: (3)

Nuclear properties, size, mass, spin, binding energy, electric and quadrupole moments, empirical mass formula, stable nuclei, classification, isotopes, isotones and isobar, mass parabola for isobars.

2. Nuclear Forces: (6)

Nature of nuclear forces, Yukawa hypothesis, general properties of deuteron , ground state with square well potential, relation between range and depth, experimental evidence of tensor force, parity, admixture of D and S state. Low energy n-p scattering, Fermi Scattering length.

3. Nuclear Decay: (6)

Alpha decay: General features, Gamow theory of alpha decay.

Beta decay: General features, Fermi theory of beta decay, selection rules, Kurie plot, parity non conservation, Wu’s experiment, origin of continuous beta spectrum, neutrino properties and detection.

Gamma decay: Multipolarity of gamma rays, selection rules, gamma ray spectra and nuclear energy level, internal conversion, Mossbauer effect, interaction of gamma rays with matter.

4. Nuclear Models: (7)

Shell model, Fermi gas model, Liquid drop model, collective model.

5. Nuclear Reactions: (6)

Type of nuclear reaction, conservation laws in nuclear reaction, Q value, experimental determination of Q value, reaction induced by alpha particle, proton, neutron and gamma ray.

6. Particle Physics: (9)

Classification of elementary particles, Mesons, Baryons, leptons, basic forces of nature and their characteristics, coupling constants, Feynman diagram of basic interactions, mediators, characteristics of strange particles, internal quantum numbers, baryon numbers, lepton number, hypercharge, isospin quantum number and iso-spin symmetry in strong interaction, Eightfold way, meson Octet, baryon Octet, baryon decuplet, Quark model for baryon and mesons in Eightfold scheme, Gellman-Nishijima formula, color quantum number and quark confinement (Qualitative feature) , decay of elementary particles, conservation laws, forbidden and allowed decay of particles, qualitative discussion on neutrino oscillation.

Tutorials: (8)

Books:

1. Nuclear Physics : S.N.Ghoshal
2. Nuclear Physics : R.R. Roy and B.P.Nigam
3. Introduction to Elementary Particles: David Griffiths

M.Sc. Course in Physics
P.G. II – Third Semester
Paper: PHY/Th/303 (Atomic & Molecular Physics)

Atomic and Molecular Physics

1. Recapitulation of one electron atom; Energy eigenvalues and eigenfunctions of hydrogenic atom, parity, expectation values. (2)
2. Fine structure and hyperfine structure of one electron atom. (2)
3. Lamb-Rutherford experiment. Lamb Shift (qualitative) (2)
4. Interaction of hydrogen atom with electromagnetic radiation, absorption, stimulated and spontaneous emissions. Einstein's A and B coefficients. Selection rules. (2)
5. Normal and anomalous Zeeman effect, Paschen-Bach effect and Stark effect for one electron atom. (3)
6. Many electron atoms: Central field approximation, Slater determinant, electronic configurations – shells, subshells, degeneracies, L-S coupling, j-j coupling, Hund's rule, Lande interval rule, Hartree-Fock self-consistent field approximation. Spectra of alkali atoms.(5)
7. Molecular structure: Molecular Hamiltonian, Born-Oppenheimer approximation, electron shells of di-atomic molecules, hydrogen molecular ion by LCAO method, calculation of bond length and dissociation energy, shapes of molecular orbitals, pi and sigma bonds. (5)
8. Molecular rotation and vibration: Solution of nuclear equation, molecular roation: rigid and non-rigid rotator, centrifugal distortion, symmetric top molecules, molecular vibration: harmonic oscillator approximation and harmonicity, Morse potential. (4)
9. Molecular Spectra: Electronic, vibrational and rotational transitions in diatomic molecules, vibration-radiation spectra, Frank-Condon principle (3)
10. Raman Spectra: pure rotation Raman spectra, vibrational Raman spectra. Polarization and Raman effect. (3)
11. Lasers: Population inversion, three level laser, He-Ne laser – principle of operation, tunable lasers, laser induced reactions and isotope separation.(3)
12. Introduction to spin resonance spectroscopy, NMR and ESR (3)

Tutorial : 8 periods

Books:

1. Physics of atoms and molecules – B.H.Bransden and C.J.Joachain
2. Fundamentals of Molecular spectroscopy – C.N.Banwell
3. Molecular spectra and Molecular structure Vol. I & II - G. Herzberg

M.Sc. Course in Physics
PG-II – Third Semester
Paper: PHY/LG/315 (General Lab. II)

1) e/m Experiment.
2) Electron Spin Resonance Spectrometer.
3) Lattice Dynamics.
4) Transmission line Characteristics.
5) Michelson Interferometer

M.Sc. Course in Physics

#Elective Subjects: (Paper: PHY/ThE/304,402,403)

1. (Quantum Field Theory -Elective)

1. Lorentz Group (5)
Continuous and discrete transformations, Group structure, Proper and improper Lorentz Transformations, SL(2,C) representations, Poincare group.

2. Canonical quantization of free fields (9)
Real and complex scalar fields, Dirac field, electromagnetic field, Bilinear covariants, Projection operators, Charge conjugation and Parity on scalar, Dirac and electromagnetic fields.

3. Interacting fields (6)
Interaction picture, Covariant perturbation theory, S-matrix, Wick's theorem, Feynman diagrams.

4. QED (9)
Feynman rules, Example of actual calculations: Rutherford, Bhabha, Moeller, Compton, $e^+ e^- \rightarrow \mu^+ \mu^-$. Decay and scattering kinematics. Mandelstam variables and use of crossing symmetry.

5. Higher order corrections (6)
One-loop diagrams. Basic idea of regularization and renormalization. Degree of divergence. Calculation of self-energy of scalar in φ^4 theory using cut-off or dimensional regularization.

6. Gauge theories (10)
Gauge invariance in QED, non-abelian gauge theories, QCD (introduction), Asymptotic freedom, Spontaneous symmetry breaking, Higgs mechanism.

BOOKS:
1. M.E. Preskin and D.V. Schreder, An Introduction to Quantum Field Theory.
2. Ashok Das, Lectures on Quantum Field Theory.
3. A. Lahiri and P. Pal, A First Book in Quantum Field Theory.

2. (High Energy Physics-Elective)

1. Type of interaction between the elementary particles, Feynman diagram, mediators, hadrons, basic building blocks of nature quark and leptons, resonance particles, internal quantum numbers and Gellman Nishijima formula. The Eightfold way, Quark model of mesons and baryons. Decay of elementary particles, symmetries and conservation laws, charge conjugation, CP violation in weak interaction, CPT theorem, properties of neutrinos, parity, quark-lepton symmetry, Neutrino oscillations. (8)

2. Hadron spectroscopy, Multiplets and quarks. Quark flavours, SU(2) representation-fundamental representation of SU(2) doublet, iso spin, conjugate and regular representation of SU(2). Representation of SU(3), Young Tableaux. (10)

3. Invariant Lagrangian, U(1) symmetry, Global ly and locally invariant lagrangians, Gauge fields, Degeneracy of vacuum states and spontaneous breakdown of symmetry, Standard model of electroweak interaction-construction of lagrangian SU(2)* U(1) group, extension of standard model to include quarks (qualitative) (12)

4. Dynamical structure of hadrons, deep inelastic scattering, structure function, Bijorken scaling, exact scaling and scaling violation. (8)

5. Theory of strong interaction, introduction of colour degree of freedom, quantum chromo dynamics(QCD), gluons, running coupling constant and asymptotic freedom.(7).

Books:

1. Introduction to Elementary Particles: David Griffiths
2. An introduction to Quarks and Partons: F.E. Close.
3. Introduction to Gauge Field Theories: M Chaichian and N.F. Nelipa.

3. (Nonlinear Dynamics -Elective)

1. Introduction (13)
One-dimensional systems: Flows on the line. Fixed points and stability, graphical analysis, linear stability analysis. Existence and uniqueness of solutions. Impossibility of oscillations in one dimension. Flows on the Circle : Possibility of oscillations, Superconducting Josephson Junction, Equivalent circuit and damped, driven pendulum analogue.
Bifurcations in one dimensional systems and their classifications. Imperfect bifurcations and catastrophes.

2. Two-Dimensional Flows (12)
(a) Linear Systems and classification. Nonlinear systems: linearization and Jacobian matrix, analysis in polar coordinates. Conservative systems, reversible systems. (b) Lyapunov function, gradient systems, Dulac criterion, limit cycle, Poincare-Bendixson theorem, Lienard systems. Analysis of two widely separated time-scales.

3. Chaos I (10)
One dimensional map : Stability, Liapunov exponent, chaos; Logistic map : period-doubling route to chaos, estimation of α and δ from renormalisation arguments.

4. Chaos II (10)
Fractals : examples and dimension; Rayleigh-Benard convection : basic equations, Boussinesq aproximation; Lorenz map : Stability of fixed points and appearence of strange attractors; Baker's map; Henon map.

BOOKS:

1. S. H. Strogatz, Nonlinear Dynamics and Chaos
2. R.L. Devaney, An Introduction to Chaotic Dynamical Systems.
3. D.W. Jordan and P. Smith, Nonlinear Ordinary Differential Equations.
4. G.L. Baker and J.P. Gollub, Chaotic Dynamics - An Introduction.

4. (Astrophysics -Elective)

1. Basic Astronomy (3)
Mass, length and timescales, Celestial coordinates, Magnitudes, Astronomy at different wavelengths.

2. Radiative Transfer (6)
Equations of radiative transfer, Optical depth, Opacity, Local thermodynamic equilibrium, Spectral line formation.

3. Stellar Structure and Evolution (6)
Hydrostatic equilibrium, Virial theorem, Energy transport, Convective Instability, HR Diagram, Stellar evolution, Eddington luminosity limit.

4. Nucleosynthesis (3)
Nuclear reaction and elemental burning in stellar interiors, Solar neutrino problem.

5. Stellar Collapse (3)
Degeneracy pressure, Chandrasekhar mass limit, White Dwarfs, Neutron Stars and Pulsars as physical extremes of nature.

6. Stellar Dynamics (7)
Virial theorem for dynamics, Collisional relaxation, Incompatibility of thermodynamics equilibrium and self-gravity, Bolztmann equation, Jeans equation.

7. Plasma Astrophysics (8)
Basic fluid and plasma equations, Jeans instability, Magnetohydrodynamics and dynamo theory.

8. Cosmology (6)
Spacetime fabric of the Universe, Thermal history of the Universe, Cosmic Microwave Background Radiation, Friedman-Robertson-Walker metric, Gravitational redshift, Cosmological constant.

9. Black Hole Physics (3)
Schwarzschild metric, Singularities and the concept of a horizon.

BOOKS:

1. Arnab Rai Choudhuri, Astrophysics for Physicists.
2. Baidyanath Basu, Tanuka Chattopadhyay and Sudhindra Nath Biswas, An Introduction to Astrophysics.
3. K.D. Abhayankar, Astrophysics – Stars and Galaxies.

5. (Nuclear Physics-Elective)

1. Nuclear Forces, Phenomenological two nucleon potential, Symmetry and nuclear forces, general form of two nucleon potential. Excited state of deuteron, magnetic moment and quadrupole moment of deuteron, deuteron with non central potential and deuteron D-state. (8)

2. Nuclear structure:

Vibrational model, Breathing mode, quadrupole and octupole vibration, Giant resonance, Gamow-Teller resonance, Nilsson unified model for deformed potential. Collective model-quantum mechanical treatment, Nuclear shell model-effective Hamiltonian. (12)

3. Phenomenology of two nucleon interaction, Scattering of two nucleon system, p-p scattering at high energy, phase shift analysis, S-matrix approach, Nuclear form factor. (8)

4. Interaction of nuclear radiation with matter, energy loss of heavy charged particle passing through medium, ionization, photo electric effect, Compton scattering , pair production process, Bremssrahlung process. (9)

5. Nuclear reactions: Coulomb excitation, compound nucleus formation, Direct reaction, Statistical theory of multi step compound reaction.(8)

Books:

1. Nuclear Physics: Enrico Fermi.
2. Introductory Nuclear Physics: Samuel S.M. Wong.
3. Nuclear Physics : S.N.Ghoshal
4. Nuclear Physics : R.R. Roy and B.P.Nigam

6. (Low Dimensional Structures and Quantum Well Devices -Elective)

1: Heterostructure Growth: Molecular Beam Epitaxy, Metal Organic Vapor Deposition, Chemical Beam Epitaxy.(5)

2: Low-dimensional structures: 2D, 1D and 0D structures, Nano structures, Graphene, density of states function, equilibrium concentration of carriers.(5)

3: Band Offset: Types of heterostructures, Electron Affinity, Common Anion rule, Calculation of Band Offset, Experimental methods.(5)

4: Electron States: Effective mass approximation, Energy levels of electrons in quantum wells, Superlattice, Single heterojunction, Quantum wire and dot, energy levels of holes.(7)

5: Optical Interaction phenomena, Interaction in quantum wells, Excitons, Absorption. (6)

6: Transport Properties, Solution of transport equation for 2 DEG, mobility, high field velocity, quantum Hall Effect, ballistic transport.(10)

7: Structure and Principle of operation of ; high mobility transport, resonant tunneling diode, quantum well laser, quantum well detector, modular and switch, optical bi-stable devices.(7)

Books:

1. Physics of Quantum Well Devices – B.R.Nag
2. Introduction to Nanoelectronics – V.V.Mitin, V.A. Kochelap
   and M.A. Stroscio
3. Physics of Low-dimensional semiconductors.- J.H.Davies

4. Electronic Transport in Mesoscopic Systems – S.Datta
5. Transport in Nanostructure – D.K.Ferry and S.M.Goodnick

***Advanced Subjects: (Paper: PHY/Th/401 and PHY/LA/404)

1. Advanced Electronics (Theory)

Electronic materials and Devices:

Electronic Materials

1: Conductor, semiconductor and insulator, energy bands, effective mass tensor, density of states effective mass, calculation of Fermi level, incomplete ionization of impurity levels at low temperatures, carrier collision with crystalline imperfections, matrix elements, scattering probabilities, randomizing and elastic collisions, relaxation time, dominant relaxation processes in different materials and at different temperatures. Solution of Boltzmann transport equation, relaxation time approximation, low field transport coefficient, Hall effect, magneto resistance, features of carrier transport in strong electric and magnetic fields. Cyclotron resonance. energy levels and density of states in presence of a magnetic field. Landau diamagnetism, de-hass Van alphen effect, transport behavior of excess carriers, continuity equation, Shockley-Haynes experiment, recombination processes, surface recombination, steady state and transient photoconductivity, Shockley Read theory, methods of growth of single crystals and thin film deposition, conductivity characteristics of thin films.(10)

2: Metal-semiconductor contacts: Energy band relation, surface states, depletion layer, Schottky effect, current transport processes, thermionic emission theory, diffusion theory, tunneling current, minority carrier injection ratio, characterization of barrier heights, device structures, Ohmic contact (5).

Devices

3:Bipolar transistor: current-voltage relationship, output characteristics, device modeling, Ebers-Moll equation, Gummel-Poon model, power transistor, switching transistor, hot-electron transistor.(3)

4: JFET and MOSFET: Basic characteristic, Uniform charge distribution, arbitrary charge distribution, normally off FET, general characteristics, field dependent mobility, two-region model, saturated velocity model, microwave performance, related field effect devices, current limiter, multichannel FET.(5)

5: Tunnel devices: Tunnel diode, tunneling probability, tunneling current, current-voltage characteristics, Backward diode, MISD tunnel diode, MIS switch diode, MIM Tunnel diode, Tunneling emitter transistor.(5)

6: IMPATT and transit time diode: Static and dynamic characteristics, power and efficiency, device performance, BARITT, DOVETT and TRAPATT diodes.(5)

7: Transferred electron devices: Bulk negative differential resistivity, modes of operation, Gunn diode, device performance.(5)

8: Photonic devices: visible LED, Infrared LED, sensors, photo detectors, photoconductors, photodiodes, phototransistor, solar cell, p-n photovoltaic effect. Optical fiber wave guide, index profile, numerical aperture, pulse dispersion, Multimode fiber with optimum profile, fiber optic communication systems, cables, splices and connectors, losses in optical fibers.(7)

Books:

1. Physics of Semiconductor Devices – S.M.Sze
2. Solid State Electronic Devices – B.G. Streetman and S.K.Banerjee
3. Theory of Electrical Transport in Semiconductors – B.R.Nag
4. Solid State and Semiconductor Physics – J.P.McKelvey
5. Optical Electronics – A. Yariv
6. Optical Electronics – A. Ghatak and K Thyagrajan

Advanced Electronics (Lab.)

1. Study of Dielectric Constant and Curie Temperature of Ferroelectric ceramic
2. Four Probe set-up for measuring the resistivity of very low to high resistive samples at different temperatures
3. Measurement of Magneto resistance of semiconductor
4. Measurement of coercivity, saturation magnetization, retentivity , hysteresis loss with the help of Magnetic Hysteresis loop tracer
5. Study of power supply (Solid State) : rectification, efficiency of various type of filters , effect of load, effect of regulation, regulation characteristics with the help of a complete trainer kit
6. Characteristics of Gunn diode
7. Optical transducer trainer (Model ST 2301- Scientech): Characteristics of (a) photo voltaic cell (b) photoconductive cell (c) photo transistor (d) PINH photo diode
8. With the help of Fiber Optic Trainer Kit (ST 2501 – Scientech) to study various characteristics of an optical fiber, propagation loss, bending loss, numerical aperture.
9. Characteristics of Tunnel diode

10. With the help of Power Electronics Trainer Kit(ST 2712-Scientech) to study V-I characteristics of MOSFET (PE 02), IGBT (PE 06), PUT (PE07), SCR (PE03), DIAC (PE05), TRIAC (PE04).

2. Advanced Condensed Matter Physics (Theory)

1. Lattice dynamics : (6)

3-D lattice vibration in the harmonic approximation, cyclic boundary condition, phonon frequency distribution and dispersion relations. Diffraction of X-rays and neutrons by phonons, Debye-Waller factor, equation of state of a solid.

2. Many-electron Theory : (6)

Adiabatic approximation, Self-consistent solution of Hartree and Hartree -Fock equation for electron gas.

3. Band Theory : (7)

Bloch’s theorem, equivalent and non-equivalent wave vectors; empty lattice band Fermi surface for nearly free electron model, method of tight binding, OPW, APW and KKR Methods. Symmetrized wave function, effective mass theory.

4. Electronic Properties : (7)
Transport equation, Electronic and thermal conductivity. Transport equation in presence of magnetic field, cyclotron resonance, Landau diamagnetism, de Hass-van Alphen effect

5. Dielectric Properties : (6)
Dielectric polarization, relaxation, Debye equation. Polarization catastrophe – Onsager-Kirkwood theory, Ferroelectricity – phenomenological theory of phase transition, Lyddane Sachs-Teller relation in ferro electronics

6. Optical properties of solids : (5)
Colour of crystals, photoconductivity, luminescence, exciton. Defects in solids – colour centres, other electronic centres, dislocation, diffusion

7. Superconductivity and Superfluidity : (8)
Electrodynamics of superconductors – London's equation and Pippard's (non local) equation; The BCS theory, Ginzburg – Landau theory; magnetic properties of Type – II superconductors; Josephson effect. Hg-Te superconductors.
Superfluidity – London's argument, Liquid He 3 as a dilute Fermi gas, qualitative features of London Theory.

Books:

1. Solid State Physics – N.W. Aschroft and N.D. Mermin
2. Theoretical Solid State Physics - W. Jones and N.H. March
3. Intermediate Quantum Theory of Crystalline Solids – Alexander O.E. Animalu

Advanced Condensed Matter Physics (Lab.)

1) Dependence of Hall Coefficient on Temperature.

2) Measurement of Dielectric Constant.

3) Magnetoresistance Set-up.

4) Apparatus for the Measurement of Susceptibility of Paramagnetic solution by Quincke's Tube Method.