2 years M. Sc. Program in Physics

(w. e. f. Academic Session 2019-20)

OUTLINE SYLLABUS

Classical Mechanics
(Contact hour: 3-1-0, Credit: 04)

Newton's Laws, Dynamical Systems, Stability Analysis, Phase-space Dynamics, Lagrangian Dynamics, Variational Calculus and Principle of Least Action, Two Body Central Force Problem, Scattering Problem: elastic scattering, scattering cross section, centre of mass and laboratory frames, Rutherford scattering, Rigid Body Dynamics, Hamiltonian formulations, Small Oscillations, Special theory of relativity: Internal frames, Principle and postulate of relativity, Lorentz transformations, Four- vector notation, Energy-momentum four-vector for a particle, Relativistic invariance of physical laws, Minkowski space.

Mathematical Physics
(Contact hour: 3-1-0, Credit: 04)

Complex Analysis, continuity and differentiabiliy of complex functions, complex integration, Cauchy integral theorem, Taylor and Lorentz Series, Matrices and Tensor Analysis, Eigen values and eigen vectors, coordinate transformation, Contravariant, covariant and mixed tensors, Kronecker delta, Tensor of higher rank, symmetric and skew-symmetric tensors, Differential Equations and Special functions, Bessel's equation and solutions, Legendre, associated Legendre, Green's Function and its applications, Calculus of variation and Integral Equations, Fourier Series and Transforms, simple problems and applications, Laplace Transforms, simple problems and applications, Group theory, Subgroups, Normal Subgroups, Quotient Groups, Isomorphism Theorems, Simple Groups, Jordan Holder Theorems, Sylow Theorems and applications, group actions, symmetric and permutation groups, linear groups, Probability Theory, Random variable, Binomial, Poisson, and normal distribution, and central limit theorem.

Quantum Mechanics
(Contact hour: 3-1-0, Credit: 04)

Inadequacy of classical Physics and advent of quantum physics, Schrodinger wave equations and probability interpretation, Simple potential problems–wells, tunneling through a barrier and harmonic oscillator, vector space, inner product, Hilbert-space, eigen values and eigen vectors, Postulates of quantum mechanics, Angular Momentum Algebra, Spherically Symmetric potentials, the hydrogen Atom and hydrogen like systems, Evolution of quantum systems with time, Approximation Techniques, Time-independent perturbation theory (degenerate and non-degenerate) and applications (Stark effect, Zeeman effect, Spin-orbit coupling, fine structure and anharmonic oscillator),Vibrational method and WKB approximations and their applications to 2 electron systems.

Electronics
(Contact hour: 3-1-0, Credit: 04)

Network theorems, p-n diode, Limiters, clippers, clampers, voltage multipliers, half wave & full wave rectification, Zener diode, Varactor diode. BJT, MOSFET, Amplifier, Feedback &

Oscillator Circuits, basic feedback topologies multivibrators, OP-AMP, Inverting & Non Inverting Amplifier, Op-Amp applications, Digital electronics, logical gates, Boolean algebra- De-Morgans Laws, Karnaugh maps, adders, multiplexer, Flip-Flops, A/D and D/A converters, Reversible gates and circuits.

Laboratory-1
(Contact hour: 0-0-12, Credit: 04)

Introduction: Data interpretation, and analysis, precision and accuracy, error analysis, LSF, Linear and non-linear fitting, Chi-square Test.

1. Study of thermionic emission & measurement of work function.
2. Measurement of critical potential using Franck-Hertz tube.
3. Determination of e/m ratio of electron using Thomson method.
4. Wavelength measurement of Na-source using Michelson interferometer.
5. Determination of coherence & width of spectral lines using Michelson interferometer.
6. To study the characteristics of radiation emitted by bodies at elevated temperatures (Black Body Radiation) and determine the various constants.
7. Determination of band gap of semiconductor from temperature dependence of Resistivity using Four Probe Method.
8. To study B-H loop for a given sample by CRO.

SECOND SEMESTER

Classical Electrodynamics
(Contact hour: 3-1-0, Credit: 04)

Introduction of coordinate systems, Dirac Delta function, Gauss's law, Laplace and Poisson equations, Method of Images, Boundary value problems, multipole expansion and Dielectrics, Magnetostatics, Magnetic vector potential, multipole expansion of the vector potential and magnetic field in matter, **t**ime-varying fields, Electromagnetic induction, Continuity equation, Maxwell's equations, Pointing theorem, Gauge transformations, gauge invariance, Electromagnetic waves in free space, dielectrics and conductors, Fresnel's equations, Transmission lines and wave guides, Retarded potentials, Lienard-Wiechert Potentials, fields due to a Point charge moving with constant velocity, Fields due to accelerated point charge, Four-vector and Lorentz transformation in four dimensional space; Lorentz invariants of electromagnetic fields; Transformation of electric and magnetic field vectors.

Atomic, Molecular and Laser Physics
(Contact hour: 3-1-0, Credit: 04)

Hydrogen spectrum, many electron systems, interaction energy in L-S and J-J coupling, Hartree-Fock approximation, Perturbations, Spectra of many electron systems, the influence of external fields on many electron system, Normal and anomalous Zeeman effect, Radiative transitions, Oscillator strengths, Molecular Electronic States, Born-Oppenheimer approximation, States for hydrogen molecule and molecular ion (H_2, H_2+,), Coulomb, Exchange and Overlap integral, Symmetries of electronic wave functions, Shapes of molecular orbital, Term symbol for simple molecules, Molecular spectra, Rotation spectra, vibration spectra, electronic spectra, Frank Condon principle, Raman spectra, X-ray emission spectra, ESR, NMR, Introduction to Laser and Maser, Einstein transition probabilities, Optical Pumping, Population Inversion, Ruby and He-Ne Laser.

Statistical Physics
(Contact hour: 3-1-0, Credit: 04)

Thermodynamical Parameters and Maxwell's relations, phase space and ensembles, Entropy of ideal gas, Gibbs' paradox, First and Second order transitions, Classical statistical mechanics, microcanonical, canonical, and grand canonical ensembles, partition functions, quantum mechanical ensemble theory, statistics of various quantum mechanical ensembles, Maxwell-Boltzmann, Bose-Einstein, Fermi-Dirac distributions, Ideal Bose and Fermi gases, Bose-Einstein condensation thermodynamic behaviour of an ideal Fermi gas, the electron gas, theory of white dwarf stars; Pauli paramagnetism, Einstein and Lengevin theory of Brownian motion. Mean kinetic energy of a molecule in a gas, Harmonic Oscillator, Specific heat of solid, Ising model-partition function, Sahaionization equation.

Condensed Matter Physics
(Contact hour: 3-1-0, Credit: 04)

Crystal Physics, Types of lattices, Miller indices, simple crystal structures, Crystal diffraction, Bragg's law, Reciprocal lattice, Structure factor, Lattice dynamics, Debye's theory of lattice heat capacity, Einstein's model and Debye's model of specific heat, thermal expansion, Thermal conductivity, band theory of solids, Kronig-Penny model, Semiconductors, Intrinsic carrier concentration, Mobility, Impurity conductivity, Fermi surfaces and construction, Super conductivity, Meissner effect, Entropy and heat capacity, Energy gap, Microwave and infrared properties, Type I and II superconductors, London equation, Elementary BCS Theory.

Laboratory-2
(Contact hour: 0-0-12, Credit: 04)

Introduction: Characteristics of all semiconductor diodes, transistor characteristics.

1. FET and MOSFET characterization and application as an amplifier.
2. Solving of differential equation and inductive simulation by OP-AMP and CRO.
3. Design and study of regulated power supply.
4. To study characteristics and RC, LR and LRC circuits.
5. Zeeman Effect.
6. Velocity of ultrasonic waves.
7. Absorption coefficient by spectrophotometer.

8. Analysis of line and band spectra.

THIRD SEMESTER

Nuclear and Particle Physics
(Contact hour: 3-1-0, Credit: 04)

Nuclear Constituents and their properties, Nuclear Models, Liquid drop model: Weizsacker's Semi-empirical mass formula, Bohr-Wheeler theory of fission, Spin-orbit coupling, Magic numbers, Angular momenta and parities of nuclear ground state, Magnetic moments and Schmidt lines, Collective model of a nucleus, Nuclear Forces, Yukawa potential, Nuclear reactions, Centre of mass frame in nuclear Physics, Nuclear decay, : Alpha decay, Beta decay, Fermi's theory- Fermi-Kurie Plot, Decay rates, Gamma decay, Angular correlation in successive gamma emissions, Particle physis, elementary particle, quantum numbers, Symmetry and conservation laws, Elementary ideas of CP and CPT invariance, Classification of Hadrons, Quark model, Gell-mann, Okubo mass formula for octet and decaplet Hadrons, Weak interactions.

Advanced Quantum Mechanics
(Contact hour: 3-1-0, Credit: 04)

Time dependent perturbation theory, Fermi's golden rule, Pauli exclusion principle, spin-statistics connection, Identical Particles, space and spin wave functions, consequences of particle statistics, ideal quantum gases, Bose-Einstein condensation in atomic gases, Non-relativistic Scattering Theory, scattering by central potential, phase-shift analysis, optical theorem, scattering by a square well potential, the Born approximation, Relativistic Quantum Mechanics, Klein-Gordon equation Dirac equation, physical implementation and applications, Basic ideas of quantum field theory and quantum electrodynamics, Some applications of quantum mechanics, Semiconductor, quantum devices (e.g. random number generator), quantum communications.

Numerical Techniques and Computer Programming
(Contact hour: 3-1-0, Credit: 04)

Fundamentals of Programming, high/low level languages, compilation and linking, Basic data types, Arithmetic operators, Elementary introduction to header files, printf, scanf and getch functions of Turbo C/C++, Looping, One and two dimensional arrays of various data types, Operations involving matrices and vectors, String of characters and related library functions, Functions and arrays, Structures, array of structures, unions and enumerations, Command line arguments. Dynamical memory allocation, Plotting simple geometric figures, Simple C programs covering some elementary topics in numerical analysis such as Newton-Raphson method, interpolation, numerical differentiation and integration, numerical linear algebra, Euler and Runga-Kutta methods, Basic ideas of parallel computing and introduction to the software popularly used in Physics (e.g, Mathematica and Matlab).

Special Paper-1 (Condensed Matter Physics)

Advanced Condensed Matter Physics-1
(Contact hour: 3-0-0, Credit: 03)
Basic concepts of dia-, para-, ferro- and antiferromagnetic materials, Curie paramagnets and Curie-Weiss ferromagnets, Neel Antiferromagnets, Heisenberg model, Elements of magnetic

properties of metals, Landau diamagnetism, Pauli paramagnetism, transport properties of materials, Electronic conduction in metals, Thermoelectric effects, Transport phenomena in magnetic field, Hall effect and Quantum Hall effect, Order parameter, First and second order phase transitions, Landau theory, Bragg-Williams theory, Cooper pairing and BCS theory; Ginzburg-Landau theory; Flux quantization; Super current tunneling; DC and AC Josephson effects; High-Tc superconductors.

Special Paper-1 (Applied Optics)

Optoelectronics
(Contact hour: 3-0-0, Credit: 03)

Light propagation through anisotropic media, Electro optic effect and electro optic modulators and switches, Liquid crystal devices and spatial light modulators, Acousto optic effect, acousto optic tunable filter, acousto optic deflector, scanner and spectrum analyser, Basics of nonlinear optical effects, Second harmonic generation, phase matching, quasi phase matching, Sum and difference frequency generation, parametric amplification and parametric oscillation, spontaneous parametric down conversion. Third order nonlinear optical effects, Self phase modulation and soliton formation, Cross phase modulation and four wave mixing, Stimulated Raman and Brillouin scattering, Electro optic, photorefractive and acousto optic effects and their applications, Ultrafast and intense field nonlinear optics and nonlinear optics with weak field (quantum nonlinear optics).Special topics

DEPARTMENTAL ELECTIVES

Semiconductor and Electronic Devices
(Contact hour: 3-0-0, Credit: 03)

Bonding forces and energy bands in solids, charge carriers in semiconductors, carries concentrations, Fermi level, optical absorption, Carrier lifetime and diffusion of carriers, fabrication of p-n junctions, equilibrium conditions, steady state conditions, reverse bias breakdown, recombination and generation in the transition region, metal semiconductor junctions, Field effect transistor (FET), Metal-insulator-semiconductor FET, MOS FET, photodiodes, solar cell, light emitting diodes, lasers, semiconductor lasers, Negative conductance Microwave devices: IMPATT diode, Gunn diode.

Laser and Applications
(Contact hour: 3-0-0, Credit: 03)
Review of Laser theory, properties of laser radiation, and laser safety; CW lasers systems: Ruby-, Nd:YAG- and Nd:Glass lasers, DPSS lasers, fiber lasers, gas lasers, Pulsed lasers: ns, ps, and fs lasers, excimer-, dye-, X-ray and free-electron lasers; Semiconductor lasers: DH, QW, QCL, VCSEL, DFB and DBR lasers; Application of lasers in data storage, communication and information technology; Laser applications in optical metrology; Surface profile and dimensional measurements; Laser Applications in material processing and manufacturing; 3D-printing, marking, drilling, cutting, welding, hardening and manufacturing; Laser Doppler velocimetry, LIDAR, laser spectroscopy, LIF, LIBS, Bio-medical applications of lasers, Laser tweezers and applications, laser applications in defense.

Quantum Optics
(Contact hour: 3-0-0, Credit: 03)

Quantization of the EM field, Coherent state and P-function, Quantum states of light (squeezed state, antibunchied state, entangled states, etc,), correlation functions, Detection of quantum light and techniques, coincidence-counting, phase-sensitive detection, quantum treatment of linear optics, Quantum light by non-linear optical processes, SPDC, signatures of quantum behaviour, Landmark experiments in quantum optics, Applications: Laser cooling and BEC, Ion trapping, CPT, EIT, slow light, Introduction to quantum communication.

Quantum Field Theory
(Contact hour: 3-0-0, Credit: 03)

Quantization of scaler fields and Dirac fields; S-matrix expansion, Wick expansion and Feynman diagram, discrete symmetries; gauge symmetries and symmetry breaking; QED; Elementary processes; higher order effects; renormalization; novel effects of QED.

Laboratory-3

Solid State Physics Laboratory
(Contact hour: 0-0-12, Credit: 04)

1. Synthesis and characterization of polymer thin films.
2. Synthesis and characterization of ceramic materials by solid state route.
3. Synthesis and characterization of Nano particles of ZnO by Chemical method.
4. Synthesis and determination of band gap of TCO by UV-VIS spectroscopy
5. Frequency and temperature dependent dielectric constant measurement by Impedance spectroscopy.
6. Preparation of thin film of required material on a given substrate using vacuum coating unit.
7. Study of microstructure (i) Polishing (ii) Etching (iii) Surface study using optical microscope.
8. To measure the magnetoresistance of semiconductor and analyze the plots of $\Delta R/R$ and log-log plot of $\Delta R/R$ Vs magnetic field.

Laboratory-3

Applied Optics Laboratory
(Contact hour: 0-0-12, Credit: 04)

1. Film thickness measurement by Interferometric method.
2. Determination of optical constants of thin films by ellipsometry.
3. To determine the V-parameter, the core radius and core cladding dielectric constant difference of step-index single mode fiber.
4. To measure the near field intensity profile of multimode fiber and hence, its refractive index profile.
5. To measure the power loss at a splice between two multimode fibers and study the variation of splice loss with transverse, longitudinal and angular offsets.
6. To determine the mode field diameter (MFD) of the fundamental mode in given single mode fiber (SMF) by a measurement of its far field.
7. Optical source to fiber coupling and Far field pattern measurements of the multimode fiber, Numerical aperture (NA) measurement.
8. Design considerations of a fiber optic link and BER measurements.

9. Optical Time Domain Reflectometry (OTDR): measurements of fiber loss, and losses due to splices and connectors in the single mode fibers.
10. Biasing characteristics of a Laser diode and spectral characterization using an Optical Spectrum Analyzer.

FOURTH SEMESTER

Special Paper-2 (Condensed Matter Physics)

Advanced Condensed Matter Physics-2
(Contact hour: 3-0-0, Credit: 03)

Mechanism of plastic deformation, origin of defects, points, line and plane defects, screw and edge dislocations, dislocation in fcc, hcp and bcc lattices, stress needed to operate Frank Read sources, electrical conductivity of thin films, Boltzmann transport equation for thin films, elementary concept of surface crystallography, scanning, tunneling and atomic microscopy.

Special Paper-2 (Applied Optics)

Fiber Optics
(Contact hour: 3-0-0, Credit: 03)

Rays and ray paths in optical fibers; Numerical aperture; Step index and graded index fibers; Attenuation in optical fibers; Modal analysis of symmetric planar waveguides; TE and TM modes, mode cut off, power flow: Linearly polarized (LP) modes in stepindexoptical fibers; Mode cutoff, single mode operation; Mode field diameter in single mode fibers, LP modes of infinitely extended parabolic medium, Intermodal dispersion in multimode fibers;, Optimum profile fibers; Dispersion and chirping of pulses in single mode fibers, Dispersion compensation and dispersion tailoring; Birefringence in optical fibers, Polarization mode dispersion; Specialty fibers: Birefringent fibers, Photonic crystal fibers; Erbium doped fiber amplifiers and lasers; Fiber optic components: fiber Bragg gratings, directional couplers; Fiber fabrication and characterization techniques; OTDR, connectors and splices.

DEPARTMENTAL ELECTIVES

Introduction to Nanoscience
(Contact hour: 3-0-0, Credit: 03)

Introduction to Nanoscience and Nanomaterials, Dimensionality Effects, Properties of Metallic, Semiconducting and Magnetic Nanomaterials, Carbon as Special Nanomaterial, Synthesis of Nanomaterials, Nucleation and Growth of thin films, Characterization and Applications of Nanomaterials.

Design and Fabrication of Solar Cells
(Contact hour: 3-0-0, Credit: 03)

Energy issues, conventional and Renewable energy sources, Solar Energy and Photovoltaics, fundamental of semiconductors, p-n junction diode, solar cell characteristics, Quantum Efficiency, loses in solar cell, solar cell design, design for high I_{sc}, V_{oc}, FF, solar simulators, solar cell technologies: production of Si, Si wafer based and thin film solar cells (Crystalline solar cells, II-VI and III-V compound solar cells (GaAs), CdTe, $CuInSe_2$, Amorphous Si, Thin Film Si), emerging solar cell technologies and concepts (DSC), solar photovoltaic modules, balance of system (BOS), design of photovoltaic system

Characterization of Solids
(Contact hour: 3-0-0, Credit: 03)

Structure and Microstructure analysis by X-ray, SEM and TEM; Composition analysis by EDX and WDX ; Molecular structure by Fourier transform IR (FTIR) and Raman spectroscopy; Electronic structure by Photoelectron Spectroscopy and X-ray absorption techniques;; Surface morphology and structure by SPM, thermal analysis by TGA,DTA,DSC.

Thin Film Deposition Techniques
(Contact hour: 3-0-0, Credit: 03)

Kinetic Theory of gases, gas transport and pumping, Vacuum pumps and vacuum systems, Physical and chemical vapor deposition of thin films techniques: e-beam, ion beam and pulsed laser evaporation, dc and ac (rf) sputtering, magnetron sputtering, hybrid and modified PVD, thermal CVD, Laser and plasma enhanced CVD, Lab session for thin film processing, Thermodynamics of nucleation-surface energies, kinetic processes in nucleation and growth, lattice misfit and defects in epitaxial films, epitaxy of compound semiconductors, Resistive components, Capacitor, Active devices, Micro-electronics, integrated circuits and other applications.

Plasma Physics
(Contact hour: 3-0-0, Credit: 03)

Introduction to Plasmas, Debye Shielding, Plasma Parameters, Dielectric Constant of Plasma and Collisions, Production of Plasmas in Laboratory, Drifts of Charged Particles under Effect of Different Combinations of Electric and Magnetic Fields, Mirror Machine, Plasma Oscillations, Space Charge Waves of Warm Plasma, Ion-Acoustic Waves and Electromagnetic Waves in Magnetized Plasma, Decay of Plasma by Diffusion, Diffusion across a Magnetic Field, Single Fluid MHD Equations, Alfven Waves, Diffusion in fully Ionized Plasmas, Plasma Instabilities, Non Linear Landau Damping, Magnetic and Inertial Confinement Fusion Schemes, ICF and ITER.

Optical and Quantum Computing
(Contact hour: 3-0-0, Credit: 03)

Basic ideas of information theory and complexity classes; bits and qubits; limitations of traditional semiconductor-based computers and different alternative strategies; Optical realization of classical computing devices, non-locality and entanglement: their generation and characterization; linear and nonlinear optical components used in computing; quantum gates and circuits and how to implement a quantum/classical gate using linear and nonlinear optical devices; teleportation, superdense coding, quantum algorithms;quantum cryptography; quantum error correction; practical quantum computers.

Integrated Optics
(Contact hour: 3-0-0, Credit: 03)

Guided TE and TM Modes of Symmetric and anti-symmetric Planar waveguides: Step index and graded-index waveguides. Strip and channel waveguides, anisotropic waveguides, Marcatili's Method, Effective-Index method and perturbation method of analysis. Directional couplers, Coupled mode analysis of uniform and reverse delta-beta couplers. Applications as power splitters, Y-junction, optical switch; phase and amplitude modulators, filters, A/D

converters, Y-splitters, Mode splitters, polarization splitters; Mach-Zehnder interferometer based devices, Acoustooptic waveguide devices. Arrayed waveguide devices, Nano-photonic-devices: Metal/dielectric plasmoniwave guides, Long and short range surface Plasmon modes supported by thin metal films, applications in waveguide polarizers and bio-sensing. Fabrication of integrated optical waveguides and devices, Waveguide characterization, end-fire and prism coupling; grating and tapered couplers, Fiberpigtailing, Nonlinear effects in integrated optical waveguides

Dissertation
(Contact hour: 0-0-20, Credit: 10)