POST GRADUATE DEPARTMENT OF PHYSICS

M.Sc. (Physics)

Session: 2020-21

Programme Specific Outcomes

The students after completion of MSc in Physics will be able to analyze physical systems on the basis of principles of basic physics topics such as classical mechanics, electrodynamics, mathematical physics, quantum mechanics and electronics. They can also interpret experimental results in terms of existing principles and laws of Physics.

- PSO 1: This course can develop the critical thinking skills of the students through acquired knowledge in major branches of physics.
- PSO 2: Learn to carry out experiments in basic as well as certain advanced areas of physics such as Condensed Matter Physics, High Energy Physics, Statistical Mechanics and Nuclear & Particle Physics.
- PSO 3: They learn the deeper meaning of different branches of physics and their interrelationships. The students are also motivated to face competitive examinations and course enhance National and International competency.
- PSO 4: They learn to tackle and troubleshoot problems during experiments at the labs.
- PSO 5: They learn the very nature of performing research work in Physics during projects.
  They can explain their research work results in project seminars.
- PSO 6: The two-year PG course – Master Degree in Science (M. Sc. Course) gives them enough opportunity to align their mental faculties and attitudes to prepare for the State and National Level Examinations (SLET, NET, UGC-CSIR, DST, UPSC, etc.) for entry to recognized Institutions and Research Organizations (IACS, SINP, SNBNCBS, CGCRI, etc.).
- PSO 7: The students are motivated for going to abroad for Research Career by virtue of National Overseas Scholarship Schemes after completion of M. Sc. Course in Physics.

POST GRADUATE DEPARTMENT OF PHYSICS
Course Outcome or Learning Outcome Two Years M.Sc. Degree Course in Physics Session: 2020 – 2021

SEMESTER 1
Paper : I half 1
COURSE NAME : Mathematical methods I

LEARNING OUTCOMES :

1. The course of complex variable helps students to apply it in electrical network theory, quantum mechanics etc. Contour integration allows to evaluate improper integrals, which appear in several problems of physics.
2. Studies on matrices provide the basic idea of linear operator, which has wide range of applications in theoretical physics.
3. The course on the vector space helps students to understand Dirac notation in quantum mechanics and also gives the general view of operators.
4. From the course of the ordinary differential equations (ODE) students learn the techniques to solve the ODE which is eventually very important to evaluate the dynamics of many classical and quantum systems.

SEMESTER 1
Paper : I half 2
COURSE NAME : Classical Mechanics

LEARNING OUTCOMES :

1. In this advance level course, our starting point is the Hamilton's principle of least action. Apart from standard application it can provide an alternate description of dynamics in terms of Hamilton-Jacobi theory – doorway to Quantum mechanics.
2. Some special topics, such as O(4) symmetries, symplectic structure of Cannonical transform and Lagrangian formalism of Rigid body dynamics are also included to mastering this subject.
3. Nonlinear dynamics : An active area of modern research. In our curriculum, an exposure to some pivotal results such as KAM theorem and route to Chaos are included.

SEMESTER 1
Paper : II half 1
COURSE NAME : Quantum Mechanics I

LEARNING OUTCOMES :

Quantum Mechanics I course is so designed that after the successful completion of the course a student may acquire some expertise Quantum way of thinking. Of courses on quantum mechanics, we thought it reasonable to start from the wave function approach that differential equations as major tools. We concentrate on the operator formalism a la Dirac. A particularly interesting point is to note that, we devote a somewhat more time on the fundamentals of the interpretation, new ideas like guiding waves etc. On the application side our students learn perturbation theory and other approximate methods.

So the outcome of the course is grooming of the students in the structure and essence of the subject.

SEMESTER 1
Paper : 2 half 2
COURSE NAME : Electronics

LEARNING OUTCOMES :

After completion the students will get knowledge in

1. Advanced analog electronics
2. Advanced digital electronics and
3. Modern instrumentation. These will also enrich his/her knowledge in practical aspects of the modern physics.

SEMESTER 1
Paper III
COURSE NAME : General Experiments I

LEARNING OUTCOMES :

After successful completion of the course students are able to:

1. The Michelson interferometer is a common configuration for optical i nterferometry. In this expt. beams of light interfered and superimposed. Negative result conclude a great conclusion: That observation confirmed an important prediction of general relativity, validating the theory's prediction of space-time distortion in the context of large scale cosmic events (known as s trong field tests). This inference is the basis of Astro-Physics.
2. From the atomic, molecular and Electronic spectra, we study the structure and properties of matter. Lande g-factor is used to study the spectra.
3. Planck’s constant (h), a physical constant was introduced by German physicist named Max Planck in 1900. The significance of Planck’s constant is that ‘quanta’ (small packets of energy) can be determined by frequency of radiation and Planck’s constant. It describes the behavior of particle and waves at atomic level as well as the particle nature of light.
4. When light shines on a photovoltaic (PV) cell – also called a solar cell – that light may be reflected, absorbed, or pass right through the cell. The PV cell is composed of semiconductor material; the “semi” means that it can conduct electricity better than an insulator but not as well as a good conductor like a metal. There are several different semiconductor materials used in PV cells. Students are able to measure and characterize new cells.

Electronics

5. The field-effect transistor (FET) is a type of transistor that uses an electric field to control the flow of current in a semiconductor FETs control the flow of current by the application of a voltage to the gate, which in turn alters the conductivity between the drain and source.
6. A multivibrator is an electronic circuit used to implement a variety of simple two- state devices such as relaxation oscillators, timers, and flip-flops. It consists of two amplifying devices (transistors, vacuum tubes, or other devices) cross-coupled by resistors or capacitors. The first multivibrator circuit, the astable multivibrator oscillator, was invented by Henri Abraham and Eugene Bloch during World War I. They called their circuit a "multivibrator " because its output waveform was rich in harmonics. Students could know the function and use of this in IT fields.
7. To demodulate a Frequency Modulated signal using FM detector. Theory: The process, in which the frequency of the carrier is varied in accordance with the instantaneous amplitude of the; modulating signal, is called„ Frequency Modulation‟. Students could know the function and use of this in IT fields.

SEMESTER 2
Paper : IV half 1
COURSE NAME : Mathematical Methods II

LEARNING OUTCOMES :

After the successful completion of the course, the students will be able to:

1. Solve different problems in relation to modern mathematics, complicated electrical circuit theory and different anisotropic properties of solids.
2. Understand the applications of Fourier and Laplace transform.
3. They will able to solve ordinary differential equations with initial condition and will able to solve physical problems in digital signal processing, image processing, theory of wave equations and many others.

SEMESTER 2
Paper : IV half 2
COURSE NAME : Quantum Mechanics II

LEARNING OUTCOMES :

1. The quantum description of transition and scattering – two very important topics are discussed in this course. Symmetry principles is a very power full analysing tool. An Attempt is taken to reveal different aspects of continues and as wll as discrete symmetries through several examples
2. Relativistic quantum mechanics – an important tool for spectroscopy , is also included in our curriculum. The property of lorentz co-varience is an essential part of any relativistic theory. Intricate connection to the symmetry principle is also discussed to make the topic more useful.

SEMESTER 2
Paper : V half 1
COURSE NAME : Classical electrodynamics

LEARNING OUTCOMES :

After successful completion of this course the students will be able to gain knowledge about the following: -

1) Review of the topics pertaining to Electrostatics and Magnetostatics. Electromagnetic induction – Faraday's law.
2) Electromagnetic fields stressing on Maxwell's equations in stationary and moving media; Energy Flow – Poynting vector; Maxwell's stress-tensor for electromagnetic fields; Electromagnetic momentum and Radiation Pressure.
3) Radiation from time-dependent sources of charges and currents – Scalar and Vector Potentials – Gauge invariance of Electrodynamics; Inhomogeneous wave equations and their solutions by Green's function method; Calculation of radiation from various sources; Electric dipole radiation.
4) Radiation from moving point charges – Leinard-Wiechert potentials; Fields from moving charges – uniform velocity, accelerated charge, and relativistic velocity; Bremsstrahlung; Synchrotron radiation; Cherenkov Radiation.
5) Radiation reaction, scattering and dispersion – energy conservation, characteristics of charged harmonic oscillator; scattering of e. m. radiation by free and bound electrons and Kramers-Kronig dispersion relation.
6) Concepts of Relativistic Electrodynamics – E. M. field tensor, covariance of Maxwell's equations; Lorentz transformation law for the e. m. fields; Field invariants and Covariance of Lorentz force equation, Energy-Momentum tensor and the conservation laws for the e. m. field; Relativistic Lagrangian and Hamiltonian of a charged particle in an e. m. field.
7) Fundamentals of Plasma Physics; Individual particle model; Magnetic mirrors; Basic equations and wave propagation – Magnetohydrodynamic approximation; Pinch effect; Plasma Oscillations and Debye length.

SEMESTER 2
Paper : V half 2A
COURSE NAME : Instrumentation

LEARNING OUTCOMES :

After completion of the course the students will be able to:

1. Learn the techniques of different instruments and concerned technologies. These technologies are used in Physics, Material Science and Engineering experiments. Thus, this topic illuminates the students about the recent state-of-the-art as well as the traditional instruments, their principles and applications in different domains of science.
2. Knowledge in radiation detectors helps the students to understand the different nuclear radiations and their containment. Besides, the students also gather experience in the field of health and medical physics, which is vital in today's world.
3. Knowledge in thin film preparations is an immense help for the students who want to build career in material science.
4. Knowledge in the Fourier transform infra-red (FTIR) spectrometer, UV-Visible spectrophotometer makes a student experienced in the sector of molecular physics as well as materials science.
5. This topic gives impetus to the students towards hands-on experience in technology and advanced instrumentation, which could be highly important for job-oriented viewpoint.

SEMESTER 2
Paper : V half 2B
COURSE NAME : Computer Programming

LEARNING OUTCOMES :

After successful completion of this course the students will be able to gain knowledge, gain first-hand experience along with problem-solving after learning about the following: -

1. Basics of - Components of a computer, Compiler, Operating Systems, etc.
2. Fundamentals of C Language – Constants and variables; Input and output statements; Reading and writing formats; Arithmetic and logical expressions; Control assignment statements; Build-in functions; Arrays; Loops, Switch operations' usage of break and continue statements; flow charts, Algorithm and programming; Pointers; Structures; Functions; File management; Allocation of memory, etc. Application to physical and real-time problems.

SEMESTER 2
Paper VI
COURSE NAME : General Experiments II

LEARNING OUTCOMES :

1. Lasers have made the revolution in the modern optical technologies but there is hardly any efforts to take up the basic understanding of laser Physics via laboratory classes at graduate and undergraduate level. A simple experiment for studying the life time of the upper laser level under lasing condition, the relaxation oscillations, measurement of threshold current and variation of laser power as a function of current in a laser diode is presented. The experiment utilizes the readily available low cost components, a key chain laser and some of the electronics instrument normally available at any undergraduate laboratory of science and engineering department.
2. The purpose of this experiment is to familiarize the student with the Geiger-Mueller counter. This counter is a widely used pulse-counting instrument for X-ray, gamma- ray, beta-particle and alpha-particle detection. It uses gas amplification, which makes it remarkably sensitive, while the simple construction renders it relatively inexpensive. The experiments that are designed to accomplish this purpose deal with the operating plateau of the Geiger tube, resolving-time corrections, half-life determinations, and the basic nuclear counting principles.
3. Current carried by charges: negative or positive or by both. So it is important to know which charges are responsible in a particular conductor. Students are able to determine the type of carriers i.e. negative or positive by Hall voltage measurement.

<u>Electronics</u>

4. Active filters have become a mature technology for harmonic and reactive power compensation of single- and three-phase electric AC power networks with high penetration of nonlinear loads. The increased severity of power quality in power networks has attracted the attention of power engineers to develop dynamic and adjustable solutions to the power quality problems in the form of active filters
5. Demodulation is achieved by **sampling the AM signal at carrier frequency**. Amplitude modulation (AM) is defined as modifying the amplitude of the carrier wave according to the message or information signal The disadvantage is that
   large audio amplifier needs to be used to amplify the message signal.
6. The Intel 8085 ("eighty-eighty-five") is **an 8-bit microprocessor produced by Intel** and introduced in March 1976. It is a software-binary compatible with the more- famous Intel 8080 with only two minor instructions added to support its added interrupt and serial input/output features. Students know the function and use of and utility of **microprocessor.**

SEMESTER 3
Paper : VII half 1
COURSE NAME : Atomic, Molecular and LASER Physics

LEARNING OUTCOMES :

1. This course is to some extent an application of Advanced Quantum Mechanical concepts and Point Group Theory. It is designed so that the students get sufficient exposure to scientific knowledge to enter into the research fields such as Chemical Physics Relativistic Quantum Field Theory and Material Science.
2. The topics in this course covers, quite well, the syllabus of all National Level Examinations, like UGC NET, GATE, etc.in the area of Atomic & Molecular Physics. The UG students (2 students) while doing this course paper got interested and performed project work in the area of Atomic and Molecular Physics.

SEMESTER 3
Paper : VII half 2
COURSE NAME : Nuclear and Particle Physics

LEARNING OUTCOMES :

After completion of the course the students will be able to:

1. get the advanced knowledge in nuclear and particle physics. Nuclear physics is important not only to understand basic physics but also to know the physics behind radiation treatments used in medical oncology. Particle physics is important to appreciate the standard model, which is the basic theory behind the three fundamental forces of the Universe.
2. Study of nuclear radiation detector helps one to understand nuclear radiations namely α, β particles and γ-rays. Besides, it also gives knowledge about the detector that could be used to contain a particular radiation.
3. The study of detectors as well as nuclear radiation is important in medical physics also, especially for oncological purposes. Therefore, this topic has immense importance in human life.
4. Nuclear reaction gives knowledge in the development of nuclear physics experiments as well as concerned theories.
5. The study of nuclear astrophysics and reactions helps a student to understand how our universe is created, as described in the existing theories. The existence of elements in the earth can also be perceived with the help of nuclear astrophysics.
6. The study of nuclear reaction, especially the fission and fusion, gives knowledge how human society can use science for good as well as evil purposes i.e for the benefit or destruction of the society.
7. Knowledge in particle physics is highly important in today's era when a large number of countries are trying to unfold the mysteries behind the creation of universe through experiments using Large Hadron Collider (LHC) at CERN, Europe. Besides, from the standpoint of career, the topic has immense importance too.

SEMESTER 3
Paper : VIII half 1
COURSE NAME : Statistical Mechanics

LEARNING OUTCOMES :

1. Statistical mechanics provides the way to understand physical systems microscopically and also makes correlations with the macroscopic properties.
2. Quantum statistical mechanics helps the students to understand the low temperature behavior of system.
3. From the study of Ising model students get the basic idea of magnetism.
4. Knowledge of statistical physics enormously helps the students in doing research works in many advance branches of physics e.g., condensed matter physics, particle physics.

SEMESTER 3
Paper : VIII half 2
COURSE NAME : Solid State Physics

LEARNING OUTCOMES :

After successful completion of this course students will be able to:

1. Learn how solid materials could be classified into amorphous and crystallography. Different types of lattice structure; Bravis lattice, symmetry of periodicity. Learn about how properties of matter depend on structure as well as electronic configuration. They also learn how structure of matter could be studied by X-ray.
2. Know how lattice oscillate and influence the properties of the matter. Know about Mono atomic and diatomic lattice vibration, idea about acoustical and optical band of frequency, forbidden zone.
3. Know magnetic properties and type of magnetic properties of matter. Know difference among diamagnetism, paramagnetism and ferromagnetism and few established theory on magnetism. Dielectric properties of matter. Drude's theory of conduction of electron through matter, drift velocity etc.
4. How band theory develope and fruitfully explain most of the properties of matter. know a newly emerged material properties called superconductivity and its application. Critical temperature and critical magnetic field which are responsible for
breaking of superconductivity, type-I and Type-II superconductors and BCS theory
on superconductivity

SEMESTER 3
Paper IX
COURSE NAME : Numerical Methods

LEARNING OUTCOMES :

1. Teaching the Numerical Methods Course is basically using C and Fortran-77, 90 Languages. Firstly, it helped students to learn and enhance their computer language skill.
2. Secondly, the goal is to demonstrate how different numerical methods are used to solve the problems that physicists face.
3. Thirdly, the students obtain a numerical solution of different physical problems (from Advanced Classical Mechanics involving Non-Linear Equation (NLE) and Quantum Mechanical Schrödinger problems) and thus improves understanding physics which, otherwise we cannot provide experimental setup.
4. Fourthly, students get confidence to carry out Theoretical Research projects in Fourth Semester.

SEMESTER 4
Paper : Paper X half 1
COURSE NAME : Condensed Matter Physics (Advanced paper I)

LEARNING OUTCOMES :

After successful completion of this course the students will be able to gain knowledge about the following: -

1) Understanding of the basic Hamiltonian in a solid with a stress on electronic and ionic parts and the adiabatic approximation. Concepts of single particle approximation of the many-electron system concentrating on the single product and determinantal wave functions along with matrix elements of one and two- particle operators. Introduction to the Hartree-Fock (H-F) theory – the H-F equation, exchange interaction and exchange hole, Koopmans theorem, the occupation number representation – the many-electron Hamiltonian in occupation number representation and the H-F ground state energy.
2) Quasi electrons and Plasmon pertaining to the interacting free-electron gas – H-F approximation, single-particle energy levels, and the ground state energy. Perturbation theoretic calculation of the ground state energy, Correlation energy with stress on the shortcomings with the second order perturbation theoretic calculation. Wigner's interpretation for lowand high energy electron density limit, along with Wigner interpolation formulation. Cohesiveenergy in metals – Screening and Plasmons with a view for interesting experimental observations. The dielectric function of the electron gas, Friedel oscillation, Quasi-electrons, Landau's quasi- particle theory of Fermi liquid, Strongly correlated electron gas and Mott transition.
3) Spin-spin interaction (Magnons) – The explanation for various exchange interaction (Direct, Super, Indirect, and Itinerant). Spin-waves in ferromagnets – Magnons, Spontaneous magnetization, and thermodynamics of magnons. Ferromagnetic domains – Anisotropy energy and Bloch wall. Spin-waves in lattices with a focus on ferri- and anti-ferromagnetism, Collective electron model and Kondo effect. Measurement of magnon spectrum.
4) Superconductivity – Formation of Cooper pairs, BCS theory, Ginzburg-Landau theory and London equation, Meissner effect, Type II superconductors-characteristic length, Josephson effect, and "Novel High Temperature" superconductors.
5) Disordered in condensed matter – configurational and various types of disorder, Short and Long range order in medium, Atomic and Structural correlation function, Glasses and Liquids, Anderson model for random systems and electron localization. Concept of mobility edge, and idea of amorphous semiconductorsand hopping conduction.

SEMESTER **4**
Paper **: Paper X half 1**
COURSE NAME **: High Energy Physics (Advanced paper I)**

LEARNING OUTCOMES :

After successful completion of this course the students will be able to gain knowledge in the area of High Energy Physics (HEP) after learning about the following: -

1. Introduction to Classical fields; Euler-Lagrange equations; Symmetry transformations, Noether's theorem; space-time and internal symmetries.
2. Lorentz group – transformations – continuous and discrete, proper and improper; Group structure, representations (scalar, vector, tensor, spinor, etc.), SL(2,C) representations, bilinear covariant, trace relations; Chirality and helicity; Chiral symmetry-Noether currents, PCAC; Poincare group.
3. Canonical quantization of freefields – Real and complex scalar fields, Dirac field; Propagators; Discrete transformations (Parity, Time reversal and Charge conjugation) on scalar, Dirac and e. m. fields.
4. Interacting fields – interaction picture, covariant perturbation theory, S-matrix, Wick's theorem; Feynman diagrams and rules.
5. Particle physics preliminary concepts –Relativistic kinematics; Mandelstam variables and use of crossing symmetry; decay rates and Scattering cross-sections.
6. Quantum Electrodynamics – Feynman rules; Examples of actual calculations chosen from Rutherford, Bhabha, Moller-Compton scattering.
7. Introduction to functional methods – Path integral in quantum mechanics, functional derivatives, generating functional, Scalar field theory in functional form; Functional approach to Gauge theories-quantization of electromagnetic field.
8. Higher order corrections – One loop diagram, degree of divergence, basic idea of regularization and renormalization; Calculation of self-energy of scalar phi-fourth theory using cut-off or dimensional regularization.

a. Hadron structure – Elastic e-p scattering, electromagnetic form-factors, electron- hadron deep inelastic scattering, structure functions, scaling, sum rules, neutrino production.

SEMESTER **4**
Paper **: Paper X half 2**
COURSE NAME **: Condensed Matter Physics (Advanced paper II)**

LEARNING OUTCOMES :

After successful completion of this course students will be able to:

1. Learn the concepts of point group; Point groups and Bravais lattices; crystal symmetry – space groups; Experimental determination of space groups; Symmetry and degeneracy - crystal field splitting; Kramer's degeneracy; Quasicrystals – general idea; approximate translational and rotational symmetry of two-dimensional Penrose tiling; Frank-Casper phase in metallic glass.
2. Learn lattice vibrations in 3-dimensions, frequency distribution function; normal coordinates and phonons; occupation number representation of the lattice Hamiltonian; Debye-Waller factor; atomic displacement and melting point; phonon-phonon interaction; interaction Hamiltonian in the occupation number representation; thermal conductivity in insulators.
3. Know about translational and rotational symmetry of electron energy in the reciprocal space; representation of bands in different schemes; plane wave; orthogonalized plane waves and the pseudopotential metod; density of states; principles of photoelectron spectroscopy. Know about motion of electrons in bands and the effective mass: concept of electron and hole. The Boltzmann transport equation and relaxation time. U-processes; thermoelectric effects; thermal conductivity; the Wiedemann-Franz law; phonon drag.
4. Know about magnetoresistance; Hall effect. cyclotron resonance, de Hass-van Alphen effect; quantum Hall effect; magnetic breakdown. Kramers-Kronig relations, direct and indirect band transition; absorption in insulators; polaritons; one-phonon absorption; optical properties of metals; skin effect and anomalous skin effect.

SEMESTER **4**
Paper **: Paper X half 2**
COURSE NAME **: High Energy Physics (Advanced paper II)**

LEARNING OUTCOMES :

After successful completion of this course the students will be able to gain knowledgein the area of High Energy Physics (HEP) after learning about the following: -

1. Lie groups – Groups, Algebras and representations; Orthogonal and unitary groups; Particular emphasis on U(1), SU(2) and SU(3) groups; Root and Weight diagrams; Young tableaus.
2. Gauge theories – Global and local symmetries-Noether currents; U(1) gauge invariance; Geometric interpretation of gauge invariance; Yang-Mills theory.
3. Quark model – Isospin and hypercharge; hadron multiplet as global SU(2) and SU(3) representations, Quark model; Invocation of colour; Heavy quarks and their hadrons.
4. Strong interactions – Quantum chromodynamics, asymptotic freedom, Gluons and jets in $e^+ e^-$ -> hadrons, scaling violation.
5. Low energy weak interactions – Fermi theory, calculations of decay width of muon and charged pion.
6. Spontaneous Symmetry breaking – Different types of symmetry breaking; Spontaneous breakdown of discrete and continuoussymmetries, Goldstone boson, Higgs mechanism.
7. Electro-weak theory – The symmetry group and its spontaneous breakdown, gauge boson and Fermion masses, neutral current, experimental tests; Calculation of FB asymmetry in $e^+ e^- \rightarrow \mu^+\mu^-$ and decay widths of W and Z bosons (only at tree-level); Higgs physics; Reasons for looking beyond the electroweak theory.
8. Flavour physics – Theory of two-flavour oscillation, Solar and atmospheric neutrino anomalies, Neutrino experiments.
9. High Energy Physics Experiments – Relative merits and demerits of e^+ e" and hadronic colliders, LEP, LHC, and B-factories.

SEMESTER 4
Paper XI
COURSE NAME : Astrophysics (Elective Paper)

LEARNING OUTCOMES :

After successful completion of this course the students will be able to gain knowledge in the area of Astrophysics (Elective) after learning about the following: -

1) Introduction to Preliminary concepts in Astrophysics
2) Solar Astrophysics – Solar system – description; Sun – size, mass, distance, density, temperature distribution, radiation, composition, different parts, energy source, radiative processes, solar neutrino problem; Planets – general features, origin of solar system.
3) Fluid Astrophysics – Hydrostatic equilibrium, Lane-Emden equations and their solutions, mass and radius of a polytropic star.
4) Stellar Evolution – Protostar, birth of a star, H-R diagram, evolution with different initial masses, Super-nova explosion & remnants.
5) Compact Stars – White Dwarf; Neutron Star; Pulsar; Black Hole.
6) Galaxy – Its formation, Classification of Galaxies; Clusters and Large-Scale structures; Quasars and active galactic nuclei; Milky way and Local group.
7) (a) Dynamics of gravitational Field – Einstein's field equations; Bianchi identities and conservation of the stress tensor, Einstein's equations for weak gravitational fields; the Newtonian limit.
(b) Schwarzschild metric and related topics - Derivation of Schwarzschild metric; Basic properties of Schwarzschild metric coordinate-systems and nature of R=2M surface; Effective potential for particle orbits in Schwarzschild metric: general properties and Gravitational Red-Shift.
(c) Astro-particle physics – Cosmic rays; on-going searches for exotic particles from extra-terrestrial sources; Gravitational waves.
(d) Cosmic phenomena – Dark matter, Dark energy, Cosmological constant and Expanding Universe.

SEMESTER 4
Paper XI
COURSE NAME : Statistical Physics (Elective Paper)

LEARNING OUTCOMES :

1. From this course students get the basic understandings of critical phenomena, universality and scaling. These are very important for doing research in statistical mechanics.
2. This course also helps the students to understand dynamics of spin systems.
3. The course on the quantum statistical mechanics is very useful for doing research in condensed matter physics.
4. The course on the Monte Carlo technique helps the students to numerically simulate the physical systems.

SEMESTER 4
Paper : Paper XII half 1
COURSE NAME : Condensed Matter Physics [Advance Experiment]

LEARNING OUTCOMES :

After successful completion of this course students will be able to measure/estimate:

1. Perform experiment to see how mono atomic and diatomic lattice vibrate and formed two separate band: Acoustical and Optical band of frequency what student learn theoretically.
2. Learn to prepare solution of metallic salts in stoichiometry ratio and measure magnetic susceptibility.
3. Knowledge about different experimental tools, like: constant current generator, power supply in different mode, gauss meter, four probe etc. Can measure magnetoresistance and its variation with temperature.
4. Can measure Curie temperature by the thermal transition of ferromagnetic substance to paramagnetic substance.
5. Know to measure band gap of a semiconductor material by measuring capacitance with temperature.

SEMESTER 4
Paper : Paper XII half 1
COURSE NAME : High Energy Physics [Advance Experiment]

LEARNING OUTCOMES :

After successful completion of this course the students will be able to get acquainted and gain knowledge in the area of experimental High Energy Physics (HEP) after learning about the following Experiments with: -

1. GM counter –

   (a) Drawing of absorption curves for beta particles emitting from RaD, Sr^{90} -Y^{90} and Tl^{204} where aluminium is used as the absorber and hence determine the range of beta’s using Feather’s analysis, Using the range – energy relation to give an estimate of kinetic energies of beta particles.

   (b) Determination of mass absorption coefficients (of Al and Pb) for the gamma ray emitting from Co^{60} and give an estimate of the energy of gamma ray.

2. Scintillation counter and SCA –

   Identification of photo-peaks of observed gamma energy distribution for given gamma sources and hence draw the calibration curve and estimate the resolving power and photo-peak efficiency of the detector. Using calibration curves to determine the energy of photo peak(s) for unknown gamma source.

3. Solid state Detector –

   (a) Measurement of the stopping power of air for alpha particle emitting from $_{95}Am^{241}$ by using ADC and multi-channel analyser and hence determine the range and energy of emitting alpha.

   (b) Life-time of μ-meson by designing coincidence experiment.

SEMESTER 4
Paper : Paper XII half 2
COURSE NAME : Project

LEARNING OUTCOMES :

1. To train the learner to investigate an open problem that requires ability of working out problems independently. To give a flavor of hands-on experience in research work. To enable the learner to prepare the finding in the form of a dissertation. Through project work students learn some new research topic which helps the students to enter the Ph.D. course after completion of M.Sc. degree.
2. Each student has to carry out a project work on a topic related to recent research interest in physics under the supervision of a supervisor. In the project work the student is expected to perform some theoretical/experimental/computational investigation.