Department of Physics and Astronomical Science
Central University of Himachal Pradesh
Shapur Campus

Program Specific Outcomes (PSO),

Program Outcomes (PO),

Course Outcomes (CO) & Course Contents

of

Master of Science in Physics (M. Sc. Physics)

School of Physical and Material Sciences

Semester-Wise Distribution of Courses:

Semester	Type of Courses	Credits	Total Credits
I	Major Courses	08	20
	Minor Courses	04	
	IDC Major course	02	
	Vocational/Skill	04	
	IKS	02	
II	Major Courses	12	20
	Minor Courses	02	
	IDC Minor Course	02	
	Vocational/Skill	02	
	IKS	02	
III	Major Courses	04	20
	Minor Courses	04	
	Vocational/Skill	04	
	Research based advanced courses	08	
IV	Major Courses	04	20
	Minor Courses	04	
	Vocational/Skill	04	
	Research Work	08	
Total			**80**

Program Specific Outcomes of Master of Science in Physics

Master in Physics (M. Sc. Physics) programme at Department of Physics and Astronomical Science, Central University of Himachal Pradesh is designed in such a way to not only acquaint the students with the latest theoretical and experimental skills by imparting highly advanced courses but, also, give them a chance to develop and identify the interdisciplinary nature of the subject. Also, to make them know and understand the traditional, indigenous knowledge of science, in general, the department is offering courses based on Indian Knowledge System (IKS). This, truly, is in consonance with the National Education Policy (NEP 2020). Along with conventional and fundamental courses, the student has an opportunity to learn highly advanced special courses during the second year of the programme. They are encouraged to undergo a rigorous training during the finalization of the M. Sc. dissertation which is based on the recent research problems giving them an opportunity to get familiar with the frontline research areas. Students who wish to pursue higher studies in the subject are, thus, well equipped to choose their branch of study in future. Physics provides the foundation for the modern technology and is the training ground for the mind. During the programme the students will get hands-on experience through well equipped labs making them ready to go on to work in applied fields. In addition, it will develop, in the students, logical thinking and critical attitude which may help them in the related field(s).

Based on these sublime initiatives, on completion of programme, the post graduates will:

PSO[1]: Have advanced ideas and techniques required in frontier areas of Physics, and develop human resource with specialization in theoretical and experimental techniques required for career in academia and industry.

PSO[2]: Gain hands on experience to work in applied fields through classroom discussions and practical exposures.

PSO[3]: Going through a culture of performance based evaluation the students shall view physics as a training ground for the mind developing a critical attitude and logical reasoning that can be applied to diverse fields.

PSO[4]: Develop an understanding of the indigenous studies and contribution of our traditional knowledge in science, in general.

PSO[5]: Develop analytical and numerical skills helping them to pursue higher studies in physics and allied areas. And have research oriented experiences by executing theoretical and experimental projects in the final semester under the supervision of the concerned faculty. They will, also, have firsthand experience on how to write a scientific reports/dissertations/research paper and present results which will be imperative for their research career in the field.

In general, the programme provides an opportunity to the student to learn the underlying laws responsible for the observed dynamics from smallest to the largest length scales.

Programme Outcomes of Master of Science in Physics

PO¹: Understands the basic concepts of physics, particularly, concepts in classical mechanics, quantum mechanics, statistical mechanic, condensed matter physics, Astronomy and physics at high energy frontier to appreciate how diverse phenomena observed in nature follow from a small set of fundamental laws through logical and mathematical reasoning.

PO²: Able to carry out experiments in basic as well as certain advanced areas of physics such as nuclear physics, condensed matter physics, nanoscience, lasers and electronics.

PO³: Understand the basic concepts of certain sub fields such as nuclear and high energy physics, atomic and molecular physics, solid state physics, plasma physics, astrophysics and general theory of relativity.

PO⁴: Equipped with advanced mathematical, theoretical and computational techniques helping them to develop analytical and simulation virtues/ abilities.

PO⁵- Pursue research career in any branch of physics.

Major Courses

Classical Mechanics

Course Code: PAS8101 **Course Type: Major**
Course Credits: 4

Course Objectives:

- *Understanding the concepts of classical mechanics which serves as a springboard for the various branches of modern physics.*
- *To explain Lagrangian and Hamiltonian formulations as alternative frameworks to explain the dynamics of any physical system.*
- *To explain Hamilton Jacobi theory and the principle of least action which provide the transition to wave mechanics while Poisson brackets and canonical transformations are invaluable in formulating the basic structure of quantum mechanics.*

Course Outcomes: After the completion of the course the student will be able to:

CO1: *understand the concepts of degrees of freedom, constraints and write the Lagrangian and/or Hamiltonian for a given system. He/she will be able to write the equations of motion to extract the dynamics of the system.*

CO2: *understand the importance of the symmetry in physics, in general and shall understand the emergence of various conservation laws as a consequence of the basic symmetry principles.*

CO3: *understand basics of scattering experiments in central force field.*

CO4: *solve differential Hamilton's equations and understand the problem in terms of Hamiltonian flow in phase space.*

CO5: *write and understand Poisson brackets and canonical transformations between canonical variables and extending it to more fundamental theories.*

CO6: *find the points of stable and unstable equilibrium, normal modes and Eigen spectrum of a dynamical system which will be helpful in modeling the thermal and kinetic properties of solids.*

Course Contents

Unit 1: Constrained motion and Lagrangian formulation: (8 hours)

- Newtonian mechanics: brief review and limitations.
- Constraints and their classification with examples, principle of virtual work.
- D'Alembert's principle, degrees of freedom, generalised coordinates.
- Lagrange's equation from D'Alembert's principle.
- Lagrangian for various simple mechanical systems such as simple pendulum, Atwood machine, spherical pendulum.
- Charged particle in an electromagnetic field etc., invariance of Euler-Lagrange equations of motion under generalized coordinate transformations.
- Cyclic or ignorable coordinates integrals of motion.
- Concept of symmetry: homogeneity and isotropy, Lagrange's equations of motion for non-holonomic systems.

Unit 2: Rotating frame of reference and Central force problem:

(8 hours)

- Inertial forces in rotating frame.
- Coriolis force and its effects.
- Reduction to the equivalent one-body problem.
- Stability of orbits, conditions for closure.
- Virial theorem.
- Kepler problem: inverse square law force.
- Scattering in a conservative central force field.

Unit 3: Hamilton's equation of motion, Principle of least action and Hamilton principle: (6 hours)

- Legendre transformations, Hamilton's function and Hamilton's equation of motion.
- Routhian, Configuration and phase space.
- Principle of least action, Hamilton's principle.
- Derivation of E-L equations of motion from Hamilton's principle, Derivation of Hamilton's equations of motion for holonomic systems from Hamilton's principle.
- Invariance of Hamilton's principle under generalized coordinate transformation.
- Lorentz invariance of Hamilton's principle functions for the relativistic motion of a free particle.

Unit 4: Canonical transformations:

(5 hours)

- Equations of canonical transformation (CT), generating functions.
- Properties and examples of canonical transformations.
- Liouville's theorem, Area conservation property of Hamiltonian flows.
- Poisson brackets (PB), Poisson's theorem.
- Invariance of PB under CT, angular momentum Poisson brackets

Unit 5: Theory of Small Oscillations: (3 hours)

- Coupled coordinates, expansion about static equilibrium.
- Normal modes, Two coupled pendulum.
- Linear triatomic molecule.

Unit 6: Hamilton Jacobi theory: (5 hours)

- Hamilton Jacobi (HJ) equation.
- Time dependent HJ equation and Jacobi theorem
- Harmonic oscillator problem as an example of the Hamilton Jacobi method.
- Action angle variables and examples.

Unit 7: Rigid body dynamics: (5 hours)

- Degree of freedom of a free rigid body.
- Euler's and Chasle's theorem
- Euler's equation of motion for rigid body
- Motion of a heavy symmetric top rotating about a fixed point in the body under the action of gravity precession and nutation.

Prescribed Textbooks:

1. Classical Mechanics, H. Goldstein.
2. Classical Mechanics, N. C. Rana and P. S. Joag, Tata McGraw-Hill.

Other Resources/Reference books:

1. Mechanics, L. D. Landau and E. M. Lifshitz.
2. Classical dynamics of particles and systems, J. Marion and S. Thornton, Brooks- Cole.
3. Analytical Mechanics, Louis N. Hand and Janet D. Finch, Cambridge University Press.
4. Classical mechanics for physics graduate students, Ernesto Corinaldesi, World Scientific publishing.
5. Introduction to classical mechanics: with problems and solutions, David Morin, Cambridge University Press.

Course Articulation Matrix of PAS8101- Classical Mechanics

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	2	2	2	3	2	1	2	3
CO2	3	2	3	1	1	2	3	1	1	3
CO3	3	3	3	1	1	2	3	2	1	3
CO4	3	2	1	1	3	2	1	2	1	3
CO5	3	2	1	1	1	2	3	1	1	3
CO6	3	3	2	1	3	3	2	1	1	3

1: Partially related
2: Moderately related
3: Strongly related

Classical Electrodynamics

Course Code: PAS8102 **Course Type: Major**
Course Credit: 4

Course Objectives:

Maxwell's theory of electromagnetic phenomenon is a basic component of all modern courses of theoretical physics and all students of physics must have a thorough knowledge of its principles and working. The basic ingredient of this theory is the concept of a field and the equations which govern the space and time evolution of these fields. These fields are called electromagnetic fields and the equations are known as the Maxwell equations. Moreover, these fields show a wave behaviour and are termed as electromagnetic waves. Visible light is an example of electromagnetic wave. In this course, we shall learn about the working and applications of the Maxwell equations and how it is consistent with the theory of relativity.

Course Outcomes:

After successful completion of this course, students shall be able to

CO1: *Evaluate the electrostatic fields and potential in free space and in a dielectric media.*
CO2: *Evaluate configuration energy of an electrostatic system.*
CO3: *Understand the production of magnetic field due to steady current and calculate magnetic fields using Boit Savart and Amperes law.*
CO4: *Understand the Maxwell's equation of electrodynamics and its applications to propagation of electromagnetic waves.*
CO5: *Understand the concept of wave guide and basic concept of plasma and confinement.*

Course Contents

Unit 1: Mathematical preliminaries **(4 hours)**

- Vector analysis: differentiation and integration.
- Dirac's delta function: representation and use.

Unit 2: Electrostatics and Magnetostatics **(6 hours)**

- Scalar and vector potentials.
- Multiple expansion of
    - Scalar potential due to a static charge distribution.
    - Vector potential due to a stationary current distribution.

Unit 3: Maxwell's theory and conservation laws **(4 hours)**

- Maxwell's equations; charge, energy and momentum conservation (Poynting's vector and Maxwell's stress tensor)

- Electromagnetic fields and wave solution.

Unit 4: Radiation from time-dependent sources of charges and currents (6 hours)

- Inhomogeneous wave equations and their solutions;
- Radiation from localised sources and multipole expansion in the radiation zone.

Unit 5: Radiation from moving point charges (10 hours)

- Lienard-Wiechert potentials;
- Fields due to a charge moving with uniform velocity;
- Fields due to an accelerated charge;
- Radiation at low velocity; Larmor's formula and its relativistic generalisation;
- Radiation when velocity (relativistic) and acceleration are parallel, Bremsstrahlung;
- Radiation when velocity and acceleration are perpendicular, Synchrotron radiation;
- Cherenkov radiation ;
- Radiation reaction, Problem with Abraham-Lorentz formula
- Limitations of classical theory.

Unit 6: Relativistic formulation of electrodynamics (10 hours)

- Introduction to special relativity: Postulates of Einstein,
- Geometry of relativity, Lorentz transformations.
- Relativistic mechanics: Proper time, proper velocity, Kinematics and dynamics.
- Four vector notation
- Electromagnetic field tensor, covariance of Maxwell's equations.

Prescribed Textbooks:

1. D. J. Griffiths: Introduction to electrodynamics, Prentice Hall.
2. W. Panofsky and M. Phillips: Classical electricity and magnetism, Addison Wesley.

Other Resources/Reference books:

1 J. Marion and M. Heald: Classical electromagnetic radiation, Saunders college publishing.
2 L. Landau and E. Lifshitz: Classical theory of fields, Pergamon Press.
3 J. Jackson: Classical electrodynamics, Wiley international.
4 M. Schwartz: Classical electromagnetic theory, Dover publication

<u>Course Articulation Matrix of PAS8102- Classical Electrodynamics</u>

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3	1	1	2	1	1	3	2
CO2	1	1	2	3	3	2	3	2	2	2
CO3	3	3	3	2	2	1	2	1	2	2
CO4	3	3	3	2	1	3	1	3	3	2
CO5	3	2	3	1	3	3	2	2	2	1

1: **Partially related**
2: **Moderately related**
3: **Strongly related**

Statistical Mechanics

Course Code: PAS8201 **Course Type: Major**
Course Credits: 4

Course Objectives: *Statistical mechanics plays an important role in understanding the bulk and thermodynamical properties of the materials. This course is designed to provide the student an opportunity to understand*

- *connection between Thermodynamics and Statistical Mechanics.*
- *to develop statistical mechanics techniques within the paradigm of ensemble approach and their application in classical ideal and real systems.*
- *to extend the statistical approach to incorporate quantum ensembles and distributions and their application in quantum ideal and real gases.*
- *to acquaint the students with statistical techniques like viral expansion, cluster integrals to understand the behaviour of real gases.*
- *to understand the statistics of spins or magnetic system using mean field theories and to understand first and second order phase transitions as discontinuities in the thermodynamical functions.*

Course Outcomes: *After the completion of the course the student will be able to*

CO1: *explain the postulates of classical and quantum statistical mechanics and their ramifications thereof. They will understand to extract the thermodynamics of the system from the statistical behaviour of the system.*

CO2: *model the real systems in terms of micro, canonical and grand ensembles and to apply the principles of ensemble approach to selected problems starting from classical ideal gas.*

CO3: *understand the basis of ensemble approach in statistical mechanics to a range of situations e.g. ideal Bose systems and Fermi systems.*

CO4: *understand the fundamental differences between classical and quantum statistics and learn about quantum statistical distribution laws. The student will be able to explain the Bose-Einstein condensation in various bosonic systems.*

CO5: *appreciate the difference between the thermodynamics of the system based on whether it is in degenerate or non-degenerate limit. The student will be able to find the stability condition of white dwarf stars.*

CO6: *to model magnetic systems using mean field theories and understand phase transition as discontinuities in various thermodynamical functions.*

Course Contents

Unit-1: Classical Statistical Mechanics **(5 hours)**

- Foundation of statistical mechanics.
- Specification of state of a system
- Contact between statistics and thermodynamic.
- Classical ideal gas, entropy of mixing
- Sackur-tetrode equation and Gibb’s paradox.

Unit-2: Ensemble Theory: Microcanonical, Canonical Ensemble **(6 hours)**

- Phase space, phase-space trajectories and density of states
- Liouville theorem

- Microcanonical ensemble: Classical Ideal gas.
- Canonical ensemble: canonical partition function(CPF, average energy in canonical ensemble,)
- Relation between CPF and Helmholtz free energy
- Equivalence of canonical and microcanonical ensembles.

Unit-3: Ensemble Theory: Grand Canonical Ensemble (5 hours)

- Factorization of Canonical Partition function: Classical ideal gas
- Maxwell velocity distribution, Equipartition theorem
- Grand canonical ensemble: Partition function
- Calculation of statistical quantities, particle density and energy fluctuations.

Unit-4: Quantum Statistical Mechanics: Statistical Distributions (6 hours)

- Density matrix, statistics of ensembles.
- statistics of indistinguishable particle.
- Harmonic oscillator at temperature T, Maxwell-Boltzmann
- Fermi-Dirac and Bose-Einstein statistics: in microcanonical and grand canonical ensemble

Unit-5: Quantum Gases (7 hours)

- Ideal quantum gases: Bose gas, Fermi gas equation of state, energy density
- Standard functions, non-degenerate case
- Degenerate Fermi gas, Sommerfeld expansion: chemical potential and specific heat of degenerate Fermi gas
- Pauli paramagnetism: low and high temperatures
- Bose-Einstein condensation: Pressure and specific heat.

Unit-6: Approximate Methods and Ising Model (7 hours)

- Cluster expansion for a classical real gas
- Virial equation of state
- Ising model, mean field theories of the Ising model in three, two and one dimensions
- Exact solutions in one-dimension.

Unit-7: Theory of Phase transition (4 hours)

- Landau theory of phase transition
- Critical indices
- Scale transformation and dimensional analysis.

Prescribed Text Books:

1. Statistical Mechanics, Kerson Huang, Wiley
2. Statistical Mechanics, R. K. Pathria and Paul D. Beale, Elsevier.

Other Resources/Reference books:

1. Statistical and Thermal Physics, F. Reif.
2. Statistical Physics, Landau and Lifshitz.
3. Statistical Mechanics, R. Kubo.

Course Articulation Matrix of PAS8201- Statistical Mechanics

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	3	3	1	2	1	3	3	1
CO2	3	2	1	2	1	2	2	3	3	2
CO3	2	3	3	3	3	3	3	2	3	2
CO4	3	3	2	1	3	2	1	1	3	2
CO5	2	2	3	3	3	1	3	3	3	3
CO6	3	3	1	2	3	3	2	3	3	1

1: Partially related
2: Moderately related
3: Strongly related

Advanced Quantum Mechanics

Course Code:PAS8202 **Course Type: Major**
Credits: 04
Course Objectives: *The purpose of the course is to develop:*

1. *The necessary physics and mathematics background obtained in the earlier courses to understand the real life quantum mechanical problems of bound states and scattering states.*
2. *The understanding of the time dependent perturbation theory, symmetries and scattering theory*
3. *Relativistic version of single particle quantum mechanics.*

Course Outcomes:
The student will be able to
CO1: *Define symmetries in a quantum system and use it to define conserved quantities.*
CO2: *Use these conserved quantities to associate quantum numbers and transitions probabilities.*
CO3: *Define scattering quantum amplitudes, and the scattering cross- sections.*
CO4: *Use relativistic quantum properties to understand modifications of energy levels.*
CO5: *The philosophy of quantum mechanics.*

Course Content

Unit 1: Symmetries in Quantum Mechanics **(12 hours)**
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.

Unit2: Identical Particles **(5 hours)**

Meaning of identity and consequences; Symmetric and antisymmetric wavefunctions; Slater determinant; Symmetric and antisymmetric spin wavefunctions of two identical particles; Collisions of identical particles.

Unit 3: Time-dependent Perturbation Theory **(8 hours)**
Time dependent perturbation theory, interaction picture; Constant and harmonic perturbations — Fermi's Golden rule; Sudden and adiabatic approximations.

Unit 4: Scattering Theory **(10 hours)**
Laboratory and centre of mass frames, differential and total scattering cross-sections, scattering amplitude; Scattering by spherically symmetric potentials; 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; Born approximation.

Unit 5: Relativistic Quantum Mechanics **(10 hours)**

Klein-Gordon equation, interpretation of negative energy states and concept of antiparticles; Dirac equation, covariant form, adjoint equation; Plane wave solution and momentum space spinors; Spin and magnetic moment of the electron; Non-relativistic reduction; Helicity and chirality; Properties of gamma matrices; Charge conjugation; Normalisation and completeness of spinors.

Unit 6: The measurement problem and recent developments **(5 hours)**

The Copenhagen interpretation, Pure states and mixed states, Bell states, Bell's inequality and proof. EPR paradox, Entanglement.

Prescribed Text Books:

1. J.J. Sakurai, *Modern Quantum Mechanics*, Addison-Wesley.
2. R. Shankar, *Principles of quantum mechanics*, Plenum Press.
3. D. J Griffiths, *Introduction to Quantum Mechanics*, Pearson Prentice Hall.
4. B. Bransden and C. Joachain, *Quantum mechanics*, PHI.
5. D. J Griffiths, *Introduction to particle physics*, Pearson Prentice Hall.

Other Resources/ Reference Books:

1. James D. Bjorken and Sidney D. Drell, *Relativistic Quantum Mechanics,* McGraw-Hill Company.
2. E. Merzbacher *Quantum Mechanics,* McGraw Hill.
3. L. D. Landau and L. M. Lifshitz, *Quantum Mechanics: Non-Relativistic Theory,* Butterworth-Heinemann.

<u>Course Articulation Matrix of PAS8202- Advanced Quantum Mechanics</u>

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	1	2	1	3	1	3	3	3
CO2	2	1	2	3	3	2	3	3	1	2
CO3	3	2	1	1	1	1	1	3	3	2
CO4	3	1	1	2	1	1	1	3	1	3
CO5	3	2	1	3	1	3	2	2	1	3

1: Partially related
2: Moderately related
3: Strongly related

Condensed Matter Physics

Course Code: PAS8203 **Course Type: Major**
Credit: 4
Course Objectives:
This course is designed to teach students the relation between the structure and properties of exhibited by the crystalline solids. The details of band theory and effect of periodic potential on energy dispersions of electron. Role of lattice dynamics in thermal properties of solids. This course also aim to introduce the students to various types of properties of materials such as dielectrics, magnetic and superconducting properties.

Course Outcomes:
CO1: *After reading this course, the students will be able to understand how the energy dispersions of the electron are affected when large number of atoms come together to form crystalline materials.*
CO2: *What is the impact of periodic potential on electronic energy states in a crystal?*
CO3: *What causes the magnetism in any material and how one can explain various type of magnetic behaviours exhibited different materials.*
C43: *The students will also be able to understand the dielectric and superconducting materials and underlying mechanisms to explain their properties.*

Course Contents

Unit 1: Structure of solids **(9 hours)**
Bravais lattice, primitive vectors, primitive unit cell, conventional unit cell, Wigner-Seitz cell; Symmetry operations and classification of 2- and 3-dimensional Bravais lattices; point group and space group (information only); Common crystal structures: NaCl and CsCl structure, close-packed structure, Zinc blende and Wurtzite structure, tetrahedral and octahedral interstitial sites, Spinel structure; Intensity of scattered X-ray, Friedel's law, Anomalous scattering; Atomic and geometric structure factors; systematic absences; Reciprocal lattice and Brillouin zone; Ewald construction; Explanation of experimental methods on the basis of Ewald construction; Electron and neutron scattering by crystals (qualitative discussion); Surface crystallography; Graphene; Real space analysis — HRTEM, STM, FIM. Non crystalline solids-Monatomic amorphous materials; Radial distribution function; Structureof vitreous silica.

Unit 2: Band theory of solids **(6 hours)**
Bloch equation; Empty lattice band; Number of states in a band; Effective mass of an electron in a band: concept of holes; Classification of metal, semiconductor and insulator; Electronic band structures in solids - Nearly free electron bands; Tight binding method - application to a simple cubic lattice; Band structures in copper, GaAs and silicon; Topology of Fermi-surface; Quantization of orbits in a magnetic field, cyclotron resonance — de Haas-van Alphen effect; Boltzmann transport equation - relaxation time approximation, Sommerfeld theory of electrical conductivity.

Unit 3: Lattice dynamics and Specific heat **(6 hours)**
Classical theory of lattice vibration under harmonic approximation; Dispersion relations of one dimension lattices: monatomic and diatomic cases, Characteristics of different modes, long wavelength limit, Optical properties of ionic crystal in the infrared region; Inelastic scattering of neutron by phonon;

Lattice heat capacity, models of Debye and Einstein, comparison with electronic heat capacity; Anharmonic effects in crystals - thermal expansion.

Unit 4: Dielectric properties of solids (6 hours)

Electronic, ionic, and orientational polarization; static dielectric constant of gases and solids; Complex dielectric constant and dielectric losses, relaxation time, Debye equations; Cases of distribution of relaxation time, Cole - Cole distribution parameter, Dielectric modulus; Ferroelectricity, displacive phase transition, Landau Theory of Phase Transition.

Unit 5: Magnetic properties of solids (9 hours)

Origin of magnetism; Diamagnetism: quantum theory of atomic diamagnetism; Landau diamagnetism (qualitative discussion); Paramagnetism: classical and quantum theory of paramagnetism; case of rareearth and iron-group ions; quenching of orbital angular momentum; Van-Vleck paramagnetism and Pauli paramagnetism; Ferromagnetism: Curie-Weiss law, temperature dependence of saturated magnetisation, Heisenberg's exchange interaction, Ferromagnetic domains - calculation of wall thickness and energy; Ferrimagnetism and antiferromagnetism.

Unit 6: Magnetic resonances (4 hours)

Nuclear magnetic resonances, paramagnetic resonance, Bloch equation, longitudinal and transverse relaxation time; spin echo; motional narrowing in line width; absorption and dispersion; Hyperfine field; Electron-spin resonance.

Unit 7: Imperfections in solids (6 hours)

Frenkel and Schottky defects, defects by non stoichiometry; electrical conductivity of ionic crystals; classifications of dislocations; role of dislocations in plastic deformation and crystal growth; Colour centers and photoconductivity; Luminescence and phosphors; Alloys, Hume-Rothery rules; electron compounds; Bragg - Williams theory, order-disorder phenomena, superstructure lines; Extra specific heat in alloys.

Unit 8: Superconductivity (6 hours)

Phenomenological description of superconductivity - occurrence of superconductivity, destruction of superconductivity by magnetic field, Meissner effect; Type-I and type-II superconductors; Heat capacity, energy gap and isotope effect; Outlines of the BCS theory; Giaver tunnelling; Flux quantisation; a.c. and d.c. Josephson effect; Vortex state (qualitative discussions); High Tc superconductors (information only).

Reference Books:

- Solid State Physics by Neil W. Ashcroft and N. David Mermin
- Introduction to Solid State Physics by C. Kittle
- Introduction to Solids by Azaroff
- Crystallography Applied to Solid State Physics by A. R. Verma and O. N. Srivastava
- Principles of Condensed Mater Physics by P. M. Chaikin and C. Lubensky
- Solid State Physics: A. J. Dekker

Course Articulation Matrix of PAS8203- Condensed Matter Physics

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	2	2	3	1	2	2	3	1
CO2	2	2	1	2	3	3	1	1	2	2
CO3	1	3	1	1	2	3	3	1	1	1
CO4	1	1	1	3	1	2	1	1	1	1

1: **Partially related**
2: **Moderately related**
3: **Strongly related**

Nuclear and Particle Physics

Course Code:PAS9101 **Course Type: Major**

Credits: 4

Course Objectives:

The course is designed to prepare the students for their CSIR-UGC National Eligibility Test (NET) for Junior Research Fellowship and Lecturer-ship. Basic nuclear properties like size, shape, charge distribution, spin and parity. Binding energy, semi-empirical mass formula; Liquid drop model, Nature of the nuclear force, form of nucleon-nucleon potential, Deuteron problem, Nuclear reactions, reaction mechanisms, Nuclear Models , Theories and spectra of Alpha, Beta and Gamma decays and their selection rules, Elementary particles, C, P, and T invariance, Symmetry groups, parity non-conservation in weak interaction, Quark Model, quark model, eightfold way, four forces, quantum electrodynamics (QED), quantum chromo dynamics (QCD), weak interactions, decay and conservation laws, unification scheme. The course gives an understanding of the nucleus at low energy.

Course Outcomes:

CO1: *The students gather advanced knowledge in Nuclear physics. The different nuclear interactions and the corresponding nuclear potentials and its dependence on the couplings are learned.*

CO2: *The knowledge helps to choose for an Advance course in Nuclear and particle Physics.*

CO3: *The students will be able to understand the structure of nuclei through nuclear models and nuclear reaction dynamics and its mechanism. Also, the students will:*

CO4: *Demonstrate knowledge of fundamental aspects of the structure of the nucleus, radioactive decay, nuclear reactions and the interaction of radiation and matter.*

CO5: *Discuss nuclear and radiation physics connection with other physics disciplines – solid state, elementary particle physics, radiochemistry, astronomy.*

Course Contents

Unit 1: General Properties of Nucleus **(8 hours)**

- Nuclear shapes and sizes: matter and charge distribution
- Quantum properties: parity, spin and magnetic dipole moment
- Mass spectroscopy, binding energy, Fusion and fission
- Semi-empirical mass formula: the Liquid drop model.

Unit 2: Nuclear Interaction **(8 hours)**

- Classification of fundamental forces, Nature of the nuclear forces, Qualitative aspects of nuclear force: Strength and range
- Two-body bound state problem (deuteron)
- Nucleon-nucleon scattering at low energies
- Saturation of nuclear forces and charge-independence and charge-

symmetry

- Nuclear reaction mechanisms, Compound nucleus reaction, Direct

- nuclear
- reactions and heavy ion reactions.

Unit 3: Nuclear Structure (8 hours)

- Evidence of shell structure
- Single particle shell model its validity and limitations
- Collective Model: rotational spectra
- Theory of α-decay and α-ray spectra
- Fermi theory of β-decay and selection rules, conditions for spontaneous emission, continuous β-ray spectrum and neutrino hypothesis
- Theory of γ-decays and selection rules.

Unit 4: Introduction to the Elementary particles (8 hours)

- Classification and properties of elementary particles and their interactions, quarks, leptons, Spin and parity assignments, iso-spin, strangeness
- Gell-Mann-Nishijima formula
- Quantum numbers and their conservation laws
- Quark model , eightfold way.

Unit 5: Elementary particles dynamics (8 hours)

- C, P, and T invariance and applications of symmetry arguments to particle reactions
- parity non-conservation in weak interaction
- Symmetry Groups-SU(2), SU(3), four forces, weak interactions, decay and
  conservation laws, unification scheme.

Prescribed Textbooks:

1. K.S. Krane: Introductory Nuclear Physics, John Wiley& Sons Ltd.
2. D. Griffiths: Introduction to Elementary particles, John Wiley & Sons, 1987.

Other Resources/Reference books:

1. B.R. Martin: Nuclear and Particle Physics, John Wiley & Sons Ltd.
2. H.A. Enge: Introduction to Nuclear Physics, Addison-Wesley (1971).
3. V.K. Mittel, R.C. Verma and S.C. Gupta: Nuclear & Particle Physics, PHD.
4. D.C. Tayal: Nuclear Physics, Himalaya Publishing House Pvt. Ltd (2008).
5. M.P. Khanna: Particle Physics, PHD.

Course Articulation Matrix of PAS9101- Nuclear and Particle Physics

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	2	2	1	1	1	3	1	3
CO2	1	3	1	2	2	1	1	1	1	2
CO3	1	1	2	3	3	3	2	2	2	2
CO4	1	1	1	2	3	1	3	1	2	2
CO5	1	1	1	2	1	1	3	3	1	2

1: Partially related
2: Moderately related
3: Strongly related

Advanced Condensed Matter Physics-II

Course Code: PAS9213 **Course Type: Major (ES-2)**
Credit: 4
Course Objectives:
This course is designed to develop the understanding of crystal symmetry and symmetry operations. Quasicrystals and related concepts. A deeper understanding of atomic vibrations and phonons (quanta of atomic vibrations) will be developed. An overview of the formalism of density functional theory will also be given in this course. Theories of electronic transport, scattering process and magneto transport properties will also be offered in this course. This course will also discuss the description of dielectric function and its role to explain the optical properties of the solids.

Course Outcomes: *After completion of this course, the students will be able to:*
CO1: *understand the concept of spacegroup and point group notations of the symmetry elements.*
CO2: *The students will also be able understand about the quasicrystals and related concepts such as Fibonacci lattice, Penrose tiling and the diffraction outcome of quasicrystals.*
CO3: *The students will also be able to understand phonons as the quantum of atomic vibrations, phonon-phonon interaction and scattering of phonons along with their relevance in physical properties.*
CO4: *This course is also supposed to develop a deeper understanding of electronic transport in the crystals.*
CO5: *This course will also enable the students to understand the microscopic description of dielectric function and its role in optical properties of the solids.*

Course Contents

Unit 1: Symmetry in crystals **(9 hours)**
Concepts of point group; Point groups and Bravais lattices; Crystal symmetry space groups; Symmetry and degeneracy - crystal field splitting; Kramer's degeneracy; incommensurate structure; Quasicrystals: general idea, Fibonacci lattice, Higher dimensional space, approximate translational and rotational symmetry of two-dimensional Penrose tiling, Diffraction from Fibonacci lattice, Frank-Casper phase in metallic glass.
Unit 2: Lattice dynamics **(10 hours)**
Classical theory of lattice vibrations in 3-dimensions under harmonic approximation; Dispersion relation: accoustical and optical, transverse and longitudinal modes; Lattice vibrations in a monatomic simple cubic lattice; Symmetry consideration of eigen vectors; Frequency distribution function; Maxima, minima and Saddle points; Frequency variation close to the critical points, Normal coordinates and phonons; Occupation number representation of the lattice Hamiltonian, Phonon phonon interaction; Neutron diffraction by lattice vibrations; Coherent and incoherent scattering, scattering cross section for one phonon, multi phonon processes, Debye - Waller factor; Atomic displacement and melting point; Thermal conductivity in insulators; Mossbauer effect.
Unit 3: Density Functional Theory **(8 hours)**
Basics of DFT, Comparison with conventional wave function approach,

Hohenberg-Kohn Theorem; Kohn-Sham Equation; Thomas-Fermi approximation and beyond; Practical DFT in a many body calculation and its reliability.

Unit-4: Electronic properties: I **(6 hours)**

The Boltzmann transport equation and relaxation time; Electrical conductivity of metals impurity scattering, ideal resistance at high and low temperatures, U processes; Thermo-electric effects; Thermal conductivity; The Wiedemann - Franz law.

Unit 5: Electronic properties: II **(7 hours)**

Electronic properties in a magnetic field; Classical theory of magneto-resistance; Hall effect and magnetoresistance in two-band model; K-space analysis of electron motion in a uniform magnetic field; magnetoresistance for open orbits, cyclotron resonance; Azbel - Kaner resonance; Energy levels and density of states in a magnetic field; Landau diamagnetism; de Haas van Alphen effect; Quantum Hall effect.

Unit 6: Optical properties of solids **(10 hours)**

Kramers - Kronig relations; Sum rules, Dielectric function for ionic lattice, Polariton dispersion, Soft mode and Ferroelectricity, Dielectric function for free electron gas; loss spectroscopy, optical properties of metals, skin effect and anomalous skin effect, Free carrier absorption in semiconductor; Interband transition - direct and indirect transition, surface and interface modes.

Reference Books:

- Condensed Matter Physics by Michael P. Marder, *John Wiley and Sons*
- Quantum Theory of Solids by C. Kittel, *John Wiley and Sons*
- Solid State Physics by Guiseppe Grosso and Guiseppe Pastori Parravicini, *Academic Press, The Elsevier Science*
- The Physics and Chemistry of Solids by Stephen Elliott, *John Wiley and Sons*
- Solid State Physics by Neil W. Ashcroft and N. David Mermin, *Haracourt College Publishers*
- Principles of Condensed Mater Physics by P. M. Chaikin and C. Lubensky, Cambridge University Press

<u>Course Articulation Matrix of PAS9213- Advanced Condensed Matter Physics-II</u>

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	1	2	1	3	3	3	3
CO2	1	2	2	3	3	3	3	2	3	3
CO3	3	2	2	3	1	1	1	1	1	1
CO4	1	2	3	3	1	3	2	2	3	2
CO5	2	2	1	3	2	1	3	2	3	3

1: Partially related
2: Moderately related
3: Strongly related

Plasma Physics-II

Course Code: PAS9216 **Course Type: Major (ES-2)**
Credits: 4
Course Objectives: *This course aimed at giving foundation course in Plasma Physics.*

Course Outcomes*: This gives details about the Quantum Mechanics and Application courses offered for Master in Science (M Sc) course in the department of Physics and Astronomical Sciences.*

CO1: *After getting this course the student will be acquainted with the basic principles Plasma Physics.*

CO2: *The students shall be able to understand fluid model of plasma system through fluid equations like Vlasov equation and Landau Damping.*

CO3: *Student shall be to understand electromagnetics of the plasmonic systems.*

CO4: *They will also be able to explain the propagation of electromagnetic waves and its different modes through the plasmonic systems.*

Course Contents

Unit-1: Elements of plasma kinetic theory: Phase space: Single particle phase space, many particle phase space, volume elements, Distribution function, Number density and average velocity, The Boltzmann equation: Collisionless Boltzmann equation, Jacobian of the transformation in phase space, Effects of particle interactions, Relaxation model for the collision term, **(10 hours)**

Unit-2: The meaning of f(**v**), Equations of Kinetic theory, The Vlasov equation, Derivation of the fluid equations, Plasma Oscillations and Landau Damping, A physical derivation of Landau Damping, BKG and Van Kampen Modes, Experimental Verification, Ion Landau Damping, Kinetic Effects in a Magnetic Field. **(06 hours)**

Unit-3: Plasma as a fluid: Relation of plasma physics to ordinary electromagnetics, The fluid equation of motion, Fluid drifts perpendicular to **B**, Fluid drifts parallel to **B**, The plasma approximation. **(05 hours)**

Unit-4: Waves in Plasma: Representation of waves, Group velocity, Plasma Oscillations, Electron plasma waves, Ion waves, Validity of plasma approximation, Comparison of Ion and electron waves, Electrostatic Electron Oscillations perpendicular to **B**, The lower hybrid frequency, Electromagnetic waves with $\mathbf{B}_0$= 0, Experimental applications, Electromagnetic waves perpendicular to $\mathbf{B}_0$, Cutoffs and Resonances, Electromagnetic wavesparallel to $\mathbf{B}_0$, Experimental consequences, Hydromagnetic waves along $\mathbf{B}_0$ or Alfven wave and magnetosonic wave, The Clemmow-Mullaly-Allis (CMA) diagram. B **(10 hours)**

Unit-5: Equilibrium and stability: Introduction, Hydromagnetic Equilibrium, The concept of β, Diffusion of magnetic field into a plasma, Classification of instabilities: Two stream instability, The Gravitational Instability, Resistive Drift Waves, The Weibel Instability **(05 hours)**

Unit 6: Nonlinear effects: Introduction, Sheaths, Ion Acoustic Shock Waves, The

Pondermotive force, Parametric instabilities.
Plasma confinement: Inertial Confinement, Magnetic Confinement **(04 hours)**

Text books/Reference books:

1. F. F. Chen, Introduction to Plasma Physics and Controlled fusion (2/e), Springer, 2009.
2. J. A. Bittencourt, Fundamentals of Plasma Physics (3/e), Springer, 2013.
3. N. A. Krall and H. W. Travelpiece, Principle of Plasma Physics, McGraw Hill, 1973.
4. R. J. Goldston and P. H. Rutherford, Introduction to Plasma Physics,(1/e) Institute of Physics Publishing, 1995.

Course Articulation Matrix of PAS9213- Plasma Physcs-II

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	3	1	2	3	2	1	1
CO2	2	2	1	1	1	3	2	3	3	2
CO3	3	3	1	3	1	2	2	3	1	3
CO4	1	2	3	2	3	2	2	3	1	1

1: **Partially related**
2: **Moderately related**
3: **Strongly related**

Gravitation and Cosmology-II

Course Code: PAS9217 **Course Type: Major (ES-2)**
Credits: 4
Course Objectives: *This course is a continuation of the previous course on General Relativity, with emphasis on the advanced concepts and research topics.*

Course Ooutcomes:
The student will be able
CO1: *Learn spacetime geometry in the light of recent and frontline research.*
CO2: *Develop the basics to understand motion of particles in curved spacetime.*
CO3: *Understand the notions of spacetime singularities.*
CO4: *Develop formula to define mass and angular momentum.*
CO5: *Understand the contributions of Stephen Hawking, Roger Penrose and others*
CO6: *towards gravitational physics and quantum gravity.*

Course Content:

Unit 1: Manifolds **(10 hours)**
Differentiable manifolds, maps on manifolds, diffeomorphisms, vectors, dual vectors, tensors, Lie derivatives, covariant derivatives, curvatures. Einstein equations. Energy conditions, weak, null, strong and dominant energy conditions: violation of energy conditions.

Unit 2: Geodesic congruences in spacetimes **(15 hours)**
Timelike geodesics: properties, Frobenius theorem, Raychaudhuri equations. Null geodesics: properties, Frobenius theorem, Raychaudhuri equations. Interpretation of shear, and expansion scalar, Focussing theorem. Unit 3: Hypersurfaces in Spacetime, Description of hypersurfaces: Definition, normal vector, induced metric. Extrinsic curvature., integration on hypersurfaces. Gauss and Codazzi equations, and their contracted form. Initial value problems: constraints, cosmological initial values. Spherical and static spacetimes, conformally flat space. Junction conditions and thin shell formalism: The first and the second junction conditions. Examples: Dust matter collapse, thin shell collapse. Null shell formaism: junction conditions, accreting black holes and cosmological phase transitions.

Unit 4: Lagrangian and Hamiltonian formalism of GR **(15 hours)**
Lagrangian formalism for spacetimes with boundaries, Einstein-Hilbert and Gibbons-Hawking- York term and their variation. Hamiltonian formulation: 3+1 decomposition, gravitational Hamiltonian, variation of the Hamiltonian, Hamilton's equations. Definition of mass and angular momentum for stationary axi-symmetric spacetimes, Komar fomulae, Bondi- Sachs mass.

Unit 5: Black Holes and their dynamics **(5 hours)**
Uniqueness theorems of black holes, Laws of black hole mechanics, Hawking radiation (brief introduction), reasons to search for a theory of quantum gravity.

Text books:
1. R.M. Wald: General Theory of Relativity, Chicago university press.

2. S. Carroll: Spacetime and gravitation, Addison-Wesley.
3. E. Poisson, Relativist's toolkit, Cambridge University press.

Reference Books:

1. J.V. Narlikar: Introduction to Cosmology, Cambridge.
2. J. Hartle- Gravity, Pearson, (2000).
3. N. M. J. Woodhouse- General relativity, Springer (2000).
4. C.W. Misner, K.S. Thorne and J.A. Wheeler: Gravitation
5. S. Chandrasekhar: An introduction to stellar structure, Cambridge Univ. press.
6. R. d'Inverno: Introducing Einstein's relativity, Oxford Univ. press (1992).

Course Articulation Matrix of PAS9217- Gravitational and Cosmology-II

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1	2	3	1	1	2	1	2
CO2	1	1	3	1	1	1	2	1	3	1
CO3	3	2	1	1	1	3	3	2	3	1
CO4	3	3	2	1	3	1	3	3	2	3
CO5	3	3	1	2	1	2	3	1	3	3
CO6	2	1	3	2	3	1	3	3	3	2

1: Partially related
2: Moderately related
3: Strongly related

Neutrino Physics

Course Code: PAS9220 **Course Type: Major (ES-2)**
Credits: 4
Course Objectives:
Elementary introduction to neutrino physics, Electroweak part of the Standard model(SM) of particle physics. Status of neutrino within SM. Possible types of Neutrino mass terms. Neutrino oscillations.

Course Outcomes:
At the end the student will be get familiar with the basic properties of neutrinos, and the different types of interactions that they undergo; Be able to describe the different sources of neutrinos, and the landmark experiments that studied them; Understand the basic theory of neutrino mass and the implications of a non-zero mass; Exhibit an understanding of the present state of the field, be able to describe the major outstanding questions and be familiar with the possible next steps towards answering these questions.
After studying this course, students shall be able to understand::

CO1: *theoretical aspects of the Fermi theory and emergence of the neutrino physics. They will be able to write the Hamiltonian of the Fermi theory and to appreciate the effect of non-zero neutrino mass near the end point spectrum of the beta decay.*
CO2: *standard model of particle physics and gauge theory and implication of the breaking of gauge symmetry. Specifically, in the leptonic sector.*
CO3: *the neutrino mass terms like Dirac and Majorana term, CP violation etc.*
CO4: *that we are surrounded by large number of neutrino sources. They are the second most abundant particle in the Universe after photon. The students will know about different sources of neutrinos.*
CO5: *Finally, they will understand the metamorphosis of neutrino as they travel from source to detector and also, its implication for teh non-zero neutrino mass.*

Course Contents

Unit 1: Neutrinos: An Introduction **(8 hours)**

- Pauli's hypothesis of neutrino
- Fermi theory of beta decay
- Difference between ν_e and $\bar{\nu}_e$ and solar neutrino detection
- Discovery of parity violation in weak interaction
- Direct measurement of neutrino helicity
- Discovery of weak neutral current and weak gauge boson
- Charge conjugation
- Helicity and Chirality operators

Unit 2: Standard Model of Electroweak interaction **(8 hours)**

- SU(2) Yang-Mills Local Gauge Invariance

- Spontaneous Symmetry Breaking. Higgs Mechanism
- The Standard Model for Quarks
- The Standard Model for Leptons

Unit 3: Neutrino Mass Terms **(8 hours)**

- Dirac mass term
- Majorana mass term
- Dirac and Majorana mass term
- Neutrino mass term in simplest case of two neutrino fields
- Seesaw mechanism of neutrino mass generation
-

Unit 4: Neutrino Mixing Matrix **(5 hours)**

- Number of phases and angles in matrix U
- CP conservation in the leptonic sector
- Standard parameterization of mixing matrix U
- Models of neutrino masses and mixings
-

Unit 5: Neutrino Sources **(3 hours)**

- Solar neutrinos: pp, CNO neutrinos, luminosity constraint, Solar neutrino problem (SNP)
- Atmospheric neutrinos and Atmospheric neutrino problem (ANP)
- Geoneutrino, Supernova neutrinos, reactor neutrinos
-

Unit 6: Neutrino Flavour Oscillation-I **(4 hours)**

- Flavour neutrino states

- Oscillation of flavour neutrinos: Two neutrino case
- Two neutrino oscillation: CP violation in the lepton sector
- Three neutrino oscillation in the leading approximation

Unit 7: Neutrino Flavour Oscillation-II: Vacuum and matter case **4 hours)**

- Evolution equation of neutrino in matter
- Propagation of neutrino in matter of constant density
- Adiabatic neutrino transition in matter: Mikheye-Smirnov-Wolfenstein (MSW) effect.

Prescribed Textbooks:

1. Introduction to Physics of Massive and Mixed neutrinos, S. Bilenky, Springer.
2. Fundamentals of Neutrino Physics and Astrophysics, C. Guinti and Chung W. Kim, Oxford University Press.

Other Resources/Reference books:

1. Gauge Theory of elementary particle physics, T. Cheng and L. Lee
2. Modern Elementary Particle Physics, G. Kane
3. Introduction to Elementary particles, David Griffiths, Wiley.

Course Articulation Matrix of PAS9220- Neutrino Physics

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	3	1	3	1	1	1	1
CO2	3	2	2	3	2	1	3	2	2	1
CO3	1	3	1	1	3	1	2	1	3	1
CO4	2	3	3	3	2	3	2	2	3	3
CO5	2	3	3	3	1	1	2	2	3	3

1: Partially related
2: Moderately related
3: Strongly related

Minor Courses

Quantum Mechanics

Course Code:PAS8104 **Course Type: Minor**
Credits: 4

Course Objectives:

The purpose of the course is to provide a comprehensive introduction and application of the quantum mechanics and develop pre-requisite for the next course 'Advanced Quantum Mechanics'. Starting from Fundamentals of Quantum Mechanics, Mathematical Formalism, Representation Theory, Eigenfunctions, Eigenvalues, Unitary Matrix, Schrodinger and Heisenberg representations; Energy Eigenvalue Problems; Matrix Representations, Angular Momentum Operators and Addition of Angular Momenta, Time Independent Perturbation Theory, Variational Principle and WKB Method.

Course Outcomes:

On completion of the course the student should have the following learning outcomes defined in terms of knowledge, skills and general competence: The student has gained knowledge about

CO1: *basic non-relativistic quantum mechanics*

CO2: *the time-dependent and time-independent Schrödinger equation for simple potentials like for instance the harmonic oscillator and hydrogen like atoms, as well as the interaction of an electron with the electromagnetic field*

CO3: *quantum mechanical axioms and the matrix representation of quantum mechanics*

CO4: *approximate methods for solving the Schrödinger equation (the variational method, perturbation theory, Born approximations)*

CO5: *spin, angular momentum states, angular momentum addition rules, and identical particles*

Course Contents

Unit 1: Fundamentals of Quantum Physics **(10 hours)**

- Schrodinger's equation, Statistical interpretation of the wave function and normalisation
- Expectation values of operators, Ehrenfest's theorems
- Stationary solutions. Normalisable and non- normalizable states
- Eigenvalues and eigenfunctions, orthornormality and completeness of solutions
- Simple one- dimensional potentials: Square- well and delta function
- Free particle: Non-normalisable solutions, wave packets, box normalisation
- Momentum space representations, Perseval's theorem.

Unit 2: Mathematical Foundations **(8 hours)**

- Finite dimensional linear vector space and inner product spaces
- Dual spaces and the Dirac notation of bra and ket
- Linear transformations (operators) and their matrix representations
- Hermitian and unitary operators and their properties
- Generalisation to infinite dimensions
- Incompatible observables, Uncertainty relation for two arbitrary operators and it's proof.

Unit 3: Quantum dynamics **(4 hours)**

- Schroedinger picture: Unitary time evolution, Schrodinger equation

- Heisenberg picture: Heisenberg operators, Heisenberg's equation of motion
- Linear Harmonic Oscillator by operator method and it's time evolution.

Unit 4: Three dimensional problems (4 hours)

- Three dimensional problems in Cartesian and spherical coordinates
- Square wells and harmonic oscillator
- Hydrogen atom, Radial equation and it's solution.

Unit 5: Angular Momentum (4 hours)

- Angular Momentum Operators and their algebra
- Eigenvalues and Eigenfunctions
- Matrix representations for different j
- Spin Angular Momentum and Addition of Angular Momenta
- Clebsch-Gordan Coefficients.

Unit 6: Time Independent Perturbation Theory (6 hours)

- Basic Concepts, Non-degenerate Energy Levels
- First and Second Order Corrections to the Wave function and Energy
- Degenerate Perturbation Theory
- Relativistic correction and Spin-orbit Interactions
- Zeeman Effect and Stark Effect.

Unit 7: The Variation Method and WKB Approximation (4 hours)

- The Variation Principle, Rayleigh-Ritz Method
- Variation Method for Excited States
- Ground State of Helium
- WKB Method, Connection Formula
- Validity of WKB Method
- Tunnelling through a Barrier and alpha decay.

Prescribed Textbooks:

1. David J. Griffiths, Introduction to Quantum Mechanics, Pearson Prentice Hall, Inc.
2. J.J. Sakurai, Modern Quantum Mechanics, Addison-Wesley ISBN 0-201-06710-2.
3. R. Shankar, Principles of Quantum Mechanics, Second edition, Plenum Press, New York.
4. E. Marzbacher, Quantum Mechanics, Wiley Student Edition, 2011.
5. Mathews and Venkateshan, Quantum Mechanics, Tata McGraw-Hill 2010.

Reference books:

1. Ashok Das, Quantum Mechanics, Tata McGraw Hill (2007).
2. Leonard. I. Schiff, Quantum Mechanics, 3 edition, Tata McGraw-Hill 2010.
3. S. Weinberg, Quantum mechanics, Cambridge University press.
4. P.A.M. Dirac, The Principles of Quantum Mechanics, Cambridge University press.
5. A. Messiah, Quantum Mechanics, Dover.

Course Articulation Matrix of PAS8104- Quantum Mechanics

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	1	3	3	2	3	3	1
CO2	2	2	1	1	2	3	1	1	1	1
CO3	2	3	3	2	3	1	1	2	1	1
CO4	2	3	2	2	2	2	2	3	3	3
CO5	1	1	3	3	1	3	2	3	3	3

1: Partially related
2: Moderately related
3: Strongly related

Astronomy and Astrophysics

Course Code:PAS8204 **Course Type: Minor**
Credits: 2

Course Objective: *The prime aim of this course is to provide a pedagogical introduction to astronomy and astrophysics both on the galactic and extragalactic scale at the post-graduation level.*

Course Outcomes:
After completing the course satisfactorily, a student will be able:
CO1: *To understand the technique in observational astronomy*
CO2: *To understand the distance ladder in the context of the size of the Universe*
CO3: *Sun and steller synthesis. Inter-steller medium*
CO4: *Galaxies and their morphology*
CO5: *Smooth and clumpy universe. The basic mathematical machinery of the background Universe.*

Course Contents

Unit1: Astronomical Scales: Astronomical Distance, Mass and Time, Scales, Brightness, adiant Flux and Luminosity, Measurement of Astronomical Quantities Astronomical Distances, Stellar Radii, Masses of Stars, Stellar Temperature. Basic concepts of positional astronomy: Celestial Sphere, Geometry of a Sphere, Spherical Triangle, Astronomical Coordinate Systems, Geographical Coordinate Systems, Horizon System, Equatorial System, Diurnal Motion of the Stars, Conversion of Coordinates. Measurement of Time, Sidereal Time, Apparent Solar Time, Mean Solar Time, Equation of Time, Calendar. Basic Parameters of Stars: Determination of Distance by Parallax Method; Brightness, Radiant Flux, and Luminosity, Apparent and Absolute magnitude scale, Distance Modulus; Determination of Temperature and Radius of a star; Determination of Masses from Binary orbits; Stellar Spectral Classification, Hertzsprung-Russell Diagram.

(10 hours)

Unit 2: Astronomical techniques: Basic Optical Definitions for Astronomy (Magnification Light Gathering Power, Resolving Power and Diffraction Limit, Atmospheric Windows), Optical Telescopes (Types of Reflecting Telescopes, Telescope Mountings, Space Telescopes, Detectors and Their Use with Telescopes (Types of Detectors, detection Limits with Telescopes).

(5 hours)

Unit 3: Physical principles: Gravitation in Astrophysics (Virial Theorem, Newton versus Einstein), Systems in Thermodynamic Equilibrium, Theory of Radiative Transfer (Radiation Field, Radiative Transfer Equation), Optical Depth; Solution of Radiative Transfer Equation, Local Thermodynamic Equilibrium

(5 hours)

Unit 4: The sun: The solar family (Solar System: Facts and Figures, Origin of the Solar System**:** The Nebular Model, Tidal Forces, and Planetary Rings, Extrasolar Planets. Stellar spectra and classification Structure. Atomic Spectra Revisited, Stellar Spectra, Spectral Types, and Their Temperature Dependence, Black Body Approximation, H R Diagram, Luminosity Classification.

(5 hours)

Unit 5: Stellar structure: Hydrostatic Equilibrium of a Star, Some Insight into a Star: Virial Theorem, Sources of Stellar Energy, Modes of Energy Transport, Simple Stellar Model, Polytropic Stellar Model. Star formation: Basic composition of Interstellar medium, Interstellar Gas, Interstellar Dust, Formation of Protostar, Jeans criterion, Fragmentation of collapsing clouds, From protostar to Pre-Main Sequence, Hayashi Line.

(5 hours)

Unit6: Nucleosynthesis and stellar evolution: Cosmic Abundances, Stellar Nucleosynthesis, Evolution of Stars (Evolution on the Main Sequence, Evolution beyond the Main Sequence), Supernovae. Compact stars: Basic Familiarity with Compact Stars, Equation of State and Degenerate Gas of Fermions, Theory of White Dwarf, Chandrasekhar Limit, Neutron Star (Gravitational Red-shift of Neutron Star, Detection of Neutron Star: Pulsars), Black Hole. The milky way: Basic Structure and Properties of the Milky Way, Nature of Rotation of the Milky Way (Differential Rotation of the Galaxy and Oort Constant, Rotation Curve of the Galaxy and the Dark Matter, Nature of the Spiral Arms), Stars and Star Clusters of the Milky Way, Properties of and around the Galactic Nucleus

(10 hours)

Unit 7: Galaxies: Galaxy Morphology, Hubble's Classification of Galaxies, Elliptical Galaxies (The Intrinsic Shapes of Elliptical, de Vaucouleus Law, Stars and Gas). Spiral and Lenticular Galaxies (Bulges, Disks, Galactic Halo) The Milky Way Galaxy, Gas and Dust in the Galaxy, Spiral Arms, Active Galaxies

(7 hours)

Unit 8: Active galaxies: 'Activities' of Active Galaxies, How 'Active' are the Active Galaxies? Classification of the Active Galaxies, Some Emission Mechanisms Related to the Study of Active Galaxies, Behaviour of Active Galaxies (Quasars and Radio Galaxies, Seyferts, BL Lac Objects, and Optically Violent Variables), The Nature of the Central Engine, Unified Model of the Various Active Galaxies

(8 hours)

Unit 9: Large scale structure & expanding universe: Cosmic Distance Ladder (An Example from Terrestrial Physics, Distance Measurement using Cepheid Variables), Hubble's Law (Distance- Velocity Relation), Clusters of Galaxies (Virial theorem and Dark Matter), Friedmann Equation and its Solutions, Early Universe and Nucleosynthesis (Cosmic Background Radiation)

(10 hours)

Prescribed Text Book:

1. The physical universe: An introduction to astronomy, F.Shu, Mill Valley: University Science Books.
2. Theoretical Astrophysics Volume I : Astrophysical Processes Padmanabhan, T. Published by Cambridge University Press..
3. Theoretical Astrophysics Volume II : Star and Stellar Systems Padmanabhan, T. Published by Cambridge University Press..
4. Theoretical Astrophysics Volume III : Galaxies and Cosmology Padmanabhan, T. Published by Cambridge University Press..
5. Introduction to cosmology, by Jayant V. Narlikar Published by Cambridge

University Press.
6. Structure formation of the Universe, by T. Padmanabhan Published by Cambridge University Press..

Reference Books:

1. Modern Astrophysics, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co.
2. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th Edition, Saunders College Publishing.
3. Fundamental of Astronomy (Fourth Edition), H. Karttunen et al. Springer
4. K. S. Krishnasamy, 'Astro Physics a modern perspective,' Reprint, New Age International (p) Ltd, New Delhi,2002.
5. Baidyanath Basu, 'An introduction to Astrophysics', Second printing, Prentice - Hall of India Private Limited, New Delhi,2001.
6. Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.

<u>Course Articulation Matrix of PAS8204- Astronomy and Astrophysics</u>

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	2	1	1	2	1	3
CO2	3	2	3	3	1	3	3	3	1	1
CO3	1	1	2	2	3	1	1	2	2	2
CO4	2	1	3	3	2	2	3	3	2	3
CO5	2	3	3	2	3	3	1	2	3	3

1: Partially related
2: Moderately related
3: Strongly related

Astronomy and Astrophysics Lab

Course Code:PAS8205L **Course Type: Minor**
Credits: 2

Course Objective: *The prime aim of this course is to provide hands-on experience of the astronomy lab.*

Course Outcomes:

After completing the course satisfactorily, a student will be able:

CO1: *To understand the technique used to analyze the astronomy data*

CO2: *To analyze the data from the astronomy archive*

CO3: *To get familiar with the night sky*

CO4: *To learn to use the astronomical software in the various electromagnetic bands.*

Course Contents:

1. To become familiar with the astronomical objects visible to naked eye in the night sky using the software Stellarium. Go For The Experiment...
2. To become familiar with the Constellations in the night sky using the software Stellarium. Go For The Experiment…
3. To identify the retrograde motion of Mars with respect to the Background stars. Go For The Experiment…
4. To identify some of the prominent spectral lines in the spectrum of our sun. Go For The Experiment…
5. To get familiar with the spectra of different stars. Go For The Experiment…
6. To extract coordinates of a star assuming a telescope in an equatorial mount. You will also learn the concept of sidereal time. Go For The Experiment…
7. To measure astronomical distances using Cepheid variables. Go For The Experiment…
8. To measure the Proper Motion of Barnard's Star. Go For The Experiment…
9. To identify a Circumpolar Star. Go For The Experiment…
10. To determine the distance and age of the cluster using Colour Magnitude Diagram. Go For The Experiment…
11. To determine Orbital Inclination of the planet Mars. Go For The Experiment…
12. To measure planetary distances Go For The Experiment…
13. To measure distance to the Moon Go For The Experiment…
14. To determine observer's location by means of the stars Go For The Experiment...

Prescribed Text Book:

1. Manual in lab.
2. Virtual Astronomy/Astrophysics Laboratory https://va-iitk.vlabs.ac.in/?page=listexp

Course Articulation Matrix of PAS8205L- Astronomy and Astrophysics Lab

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	1	2	2	3	2	3	1	2
CO2	1	3	1	3	1	1	1	2	3	2
CO3	2	2	3	3	1	2	2	2	3	3
CO4	1	3	2	1	3	1	1	3	2	1

1: Partially related
2: Moderately related
3: Strongly related

Scientific Writing and Presentation

Course Code:PAS9202L **Course: Minor**
Course Credit: 2
Course Objectives:

The course is designed to ,

CO1: *prepare scientific papers and presentations.*

CO2: *These are introduced in Tutorial sessions; effectively use Latex for creating scientific documents and beamer presentations. These are in lab session.*

CO3: *The students shall be able to use scientific report writing software which are available under CC BY license such as LaTeX etc..*

CO4: *Online available utilities such as Overleaf shall also be introduced to the students..*

Course Contents

1. **Structure of a Scientific Paper**

- How to read a Scientific Paper
- How to write a Scientific Paper
- Preparation of Tables and Graphs
- Discussion of Results
- Writing an Abstract and choosing a Title
- The way to write a good Introduction
- All about referencing and Bibliography
- Putting it all together: Journal Paper, Research report, Thesis, Book

2. Art of making Presentations

- The DOs and DON'Ts of a Good Presentation
- The Structure of a good presentation
- Tips for making good Oral Presentations

Lab Sessions:

Lab 1: Introduction to Latex

- Creating an artile with title, author and date and running it to otbain the output

Lab 2: Important parts of a scientific paper

- Structure the content as Abstract, sections, sub-sections and the use of list environments, text formatting and page setting

Lab 3: Generating tables of different styles

- Create tables with multiple columns and multiple rows

Lab 4: Inserting different types of graphs and pictures in different ways and sizes

- Understand the graphics environment by inserting differnt types and sizes of graphs

Lab 5: Typesetting equations of varying complexity

- single line equations and multiple line equations using tabular environment

Lab 6: Referencing and Bibliography

- Different styles of referencing used in various journals and how to prepare the bibtex file appropriately

Lab 7: Preparing reports and book

- How to cross reference figures, tables, equations and references and create list of figures and table of contents

Lab 8: How to use Beamer in Latex for creating presentations

- Creating Title Slide
- Outline of Presentation
- Making Bullets, Enumeration, etc
- Creating blocks
- Splitting the slide into multiple columns

Reference: Departmental Lab Manual

Course Articulation Matrix of PAS9202L- Scientific Writing and Presentation

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	2	1	2	3	2	2	3
CO2	1	1	3	3	2	2	1	1	1	3
CO3	2	1	3	2	2	1	3	2	1	1
CO4	2	3	3	1	1	1	1	1	2	2

1: Partially related
2: Moderately related
3: Strongly related

Indian Knowledge System (IKS) Courses

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A Basic Course on Indian Knowledge System

Course Code:PAS8107 **Course Type: IKS**
Credits: 2
Course Objectives:
Bhārata has a very rich and versatile knowledge system and cultural heritage. The Bhāratīya knowledge system was developed during the Vedic period, the Saraswatī-Sindhu Civilization, the Middle ages and is being practiced till the conditions of modern times. In this basic course, a special attention is given to the historical prospective of ideas occurrence in the ancient society, and implication to the concept of material world, and religious, social, and cultural beliefs. On the closer examination religion, culture and science have appeared epistemological very rigidly connected in the Bhāratīya knowledge system. As such, this land has provided invaluable knowledge stuff to the society and the world in all the spheres of life; e.g. aeronautics, astronomy, mathematics, life science, medical science, architecture, polity, trade, art, music, dance, literature, and drama.

Course Outcomes: *Over the period, most of the works were either lost or confined to the libraries or personal possessions. However, some of the activities are still in practice of the masses unknowing the scientific and practical values. Given the nature of course and diversity of the learners' fields, the course is designed to provide a broad-spectrum of the Bhāratīya knowledge system. The main objectives of this course are as follows:*

CO1: *Creating awareness amongst the youths about the true history and rich culture of the country;*
CO2: *Understanding the scientific value of the tradition and culture of the Bhārata;*
CO3: *Promoting the youths to do research in the various fields of Bhāratīya knowledge tradition;*
CO4: *Converting the Bhāratīya wisdom into the applied aspect of the modern scientific paradigm;*
CO5: *Adding career, professional and business opportunities to the youths.*

It is also believed that after completion of this course the students will get a holistic insight into the understanding the working of nature and life.

Course Contents

Unit 1: Bhāratīya Civilization and Development of Knowledge System (4 hours)

Genesis of the land, Antiquity of civilization, On the Trail of the Lost River, the Saraswatī-Sindhu Civilization, Traditional Knowledge System, Fertile Land for Knowledge Proliferation, the Vedas, Concepts and Nomenclature, Schools of Philosophy (6+3), Ancient Education System, the Takṣaśilā University, the Nālandā University, Alumni, Knowledge Export from Bhārata.

Unit 2: Arts, Literature, and Scholars (4 hours)

Art, Music, and Dance, Naṭarāja– A Masterpiece of Bhāratīya Art, Literature, Life and works of Agastya, Lopāmudrā, Vālmīki, Patañjali, Vedavyāsa, Yājňavalkya,

Gārgī, Maitreyī, Bodhāyana, Caraka, Suśruta, Jīvaka, Nāgārjuna, Kaṇāda, Patañjali, Kauṭīlya, Pāṇini, Thiruvalluvar, Āryabhaṭa, Varāhamihira, Ādi Śaṅkarācārya, Bhāskarācārya, Nīlakaṇṭha Somasutvan.

Unit 3: Science, Mathematics and Astronomy (4 hours)

Concept of Matter, Gravity, Sage Agastya's Model of Battery, Velocity of Light, Vedic Cosmology and Modern Concepts, Concepts of Zero and Pi, Number System, Pythagoras Theorem, and Vedic Mathematics; Kerala School for Mathematics and History and Culture of Astronomy, Earth is Spherical and Rotation of Earth, Bhāratīya Kāla-gaṇanā.

Unit 4: Engineering, Technology, and Architecture (4 hours)

Pre-Harappan and Sindhu Valley Civilization, Laboratory and Apparatus, Juices, Dyes, Paints and Cements, Glass and Pottery, Metallurgy, Engineering Science and Technology in the Vedic Age, Post-Vedic Records, Iron Pillar of Delhi, Rakhigarhi, Mehrgarh, Sindhu Valley Civilization, Marine Technology, and Bet–Dwārkā.

Unit 5: Life, Environment, and Health (4 hours)

Ethnic Studies, Life Science in Literature, Plants, Anatomy, Physiology, Microbiology, Agriculture, Ecology and Environment, Āyurveda, Integrated Approach to Healthcare, Medicine, Surgery, Yoga, Siddha, and Tibetan Āyurveda.

Text books:

1. Textbook on The Knowledge System of Bhārata by Bhag Chand Chauhan, Under Publication (2021).
2. Knowledge Traditions and Practices of India (CBSE Textbook Modules for Class XI) edited by Prof. Kapil Kapoor and Prof. Michel Danino, CBSE Delhi–110 092 (2012).

Reference Books:

1. Pride of India- A Glimpse of India's Scientific Heritage edited by Pradeep Kohle et al. Samskrit Bharati (2006).
2. Histrory of Science in India Volume-1, Part-I, Part-II, Volume VIII, by Sibaji Raha, et al. National Academy of Sciences, India and The Ramkrishan Mission Institute of Culture, Kolkata (2014).
3. India's Glorious Scientific Tradition by Suresh Soni, Ocean Books Pvt. Ltd. (2010).

Course Articulation Matrix of PAS9202L- Scientific Writing and Presentation

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	1	2	2	3	2	2	1	3
CO2	2	3	1	2	2	3	3	2	3	3
CO3	3	3	3	3	3	3	1	1	1	1
CO4	2	1	1	3	1	1	1	1	2	3

1: **Partially related**
2: **Moderately related**
3: **Strongly related**

Research Based advanced Courses

Elective Specialization-1

Quantum Field Theory

Course Code:PAS9111 **Course Type: Research Work (ES-1)**
Course Credit: 4
Course Objectives:
Quantum field theory is the basis of modern theory of microscopic physics. This course provides us with a set of mathematical rules which when computed for physical processes give highly accurate results. Moreover, the formulation of these quantum field theories provides deep insights towards the mathematical, physical and philosophical foundations of the microscopic world. The plan of this course is to introduce the basics of field quantization. Students will learn the quantum theoretic descriptions of the electromagnetic, the weak and the strong forces and standard electroweak theory.

Course Outcomes: Afte the completion of the course, the students wil be able to

CO1: *Quantize free fields (both canonical quantization) and shall explain Fermions as representations of the symmetry group, n -point correlations.*

CO2: *Understand dynamics of Interacting fields; Wick contractions; Feynman rules and will be able to apply it to other physical processes.*

CO3: *Calculate scattering cross-sections for simple processes (both scalar theory and QED).*

Course Contents

Unit 1: Theory of classical fields and symmetries **(6 hours)**

- Why quantum field theory, creation and annihilation operators
- relativistic notation and natural units
- Action principal and the Euler- Lagrange equations, Hamiltonian formalism, Noether theorem

Unit 2: Quantisation of free fields **(6 hours)**

- Scalar fields, field and its canonical quantization, ground state and Hamiltonian, Fock space
- Complex scalar fields and propagator
- Dirac fields, Hamiltonian, free particle solutions, projection operators
- Lagrangian, Fourier decomposition and propagators

Unit 3: S-matrix, Cross- sections and decay rates **(8 hours)**

- Evolution operator, S-matrix and Wick's theorem
- Yukawa interaction, fermion scattering, Feynman amplitude and rules
- Decay rates and scattering cross-sections
- Four fermion interaction
- Mandelstam variables

Unit 4: Quantum electrodynamics **(8 hours)**

- Classical electromagnetic fields and quantization problems
- Modified Lagrangian, propagator, Fourier decomposition, Feynman rules for photons
- Local Gauge invariance and it's consequences: U(1), SU(2) and SU(3).

- Interaction Hamiltonian, e-e scattering

Unit 5: Renormalization **(4 hours)**

- Degree of divergence, Specific Example of QED
- Self energy, vacuum polarization, Vertex function
- Regularisation of self energy, modified Coulomb interaction
- Running coupling constant, cancellation of infrared divergences

Unit 6: Non-Abelian gauge theories and Standard electroweak theory **(8 hours)**

- Spontaneous symmetry breaking, Goldstone bosons, Higgs Mechanism
- Yang-Mills theory of non-Abelian gauge fields
- Interaction of gauge fields
- Feynman rules, colour factors, QCD Lagrangian
- Gauge group, Fermions in theory
- Gauge boson decay
- Scattering processes
- Propagators, global symmetries of the model

Prescribed Text books:

1. A. Lahiri and P.B. Pal- A First Book of Quantum Field Theory 2nd edn., Narosa Pub. (2004).
2. G. Sterman- An Introduction to Quantum Field Theory, Cambridge University Press (1993).

Prescribed Reference books:

1. F. Mandl and G. Shaw- Quantum Field Theory 2nd Edition, Wiley & Sons (2010).
2. Peskin and D. Schroeder- An Introduction to Quantum Field Theory, Levant Books (2005).
3. P. Ramond- Field Theory: A Modern Primer, Westview Press (1995).
4. S. Weinberg- Quantum field theory, Cambridge University Press (1998).

Course Articulation Matrix of PAS9111- Quantum Field Theory

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	1	3	2	3	3	3	2	1
CO2	3	3	1	3	2	3	1	2	1	1
CO3	1	1	3	1	3	2	3	3	2	2
CO4										

1: Partially related
2: Moderately related
3: Strongly related

Advanced Condensed Matter Physics-I

Course Code: PAS9114 **Course Type: Research Work (ES-1)**
Credit: 4
Course Objectives:
This course is designed to teach students about the electron-electron interaction in a material. Challenges and approximations to treat many body effects while treating electrons in a material. Interaction among electronic spins and various related phenomenon. Fundamentals of Electron-phonon-electron interactions, their role in formation of cooper pairs and superconductivity. The role of Bose-Einstein condensation in phenomena of superfluidity and superconductivity. This courser will also introduce the students to the effect of disorder on the properties of solids and familiarize them with special topics like Mott-Hubbard insulators and Kondo effect.

Course Outcomes:
After reading this course, the students will be able to appreciate
CO1: *the significance of electron-electron interaction on the energy dispersion of electron. The significance of electronic spins and their interaction in the variety of magnetic properties displayed by solids.*
CO2: *This course is also expected to teach students the fundamentals of electron-phonon-electron interactions and their crucial impact on formation of cooper pairs in a material which leads to superconducting transition of a material.*
CO3: *The students will also be able to comprehend the importance of Bose-Einstein condensation in superfluidity and other related properties.*
CO4: *Towards the end of this course, the students are supposed to understand unconventional insulators known as Mott-insulators and the explanation of this unusual phenomenon by Hubbard model.*

Course Contents

Unit 1: Fundamentals of many-electron system: Hartree-Fock theory **(8 hours)**
The basic Hamiltonian in a solid: electronic and ionic parts, the adiabatic approximation; Singleparticle approximation of the many-electron system — single product and determinantal wave functions, matrix elements of one and two-particle operators; The Hartree-Fock (H-F) theory: the H-F equation, exchange interaction and exchange hole, Koopman's theorem; The occupation number representation: the many electron Hamiltonian in occupation number representation; the H-F ground state energy.
Unit 2: The interacting free-electron gas: Quasi electrons and Plasmon **(8 hours)**
The H-F approximation of the free electron gas: exchange hole, single-particle energy levels, the ground state energy; Perturbation: theoretical calculation of the ground state energy; Correlation energy — difficulty with the second-order perturbation theoretic calculation, Wigner's result at high density, low-density limit and Wigner interpolation formula; Cohesive energy in metals; Screening and Plasmons; Experimental observation of plasmons.
Unit 3: Spin-spin interaction: Magnons **(8 hours)**
Absence of magnetism in classical statistics; Origin of the exchange interaction; Direct exchange, super exchange, indirect exchange and itinerant exchange; Spin-waves in ferromagnets — magnons, spontaneous magnetisation, thermodynamics of magnons; Spin-waves in lattices with a basis — ferri- and

antiferromagnetism; Measurement of magnon spectrum; Ordered magnetism of valence and conduction electrons, Stoner's criterion for metalic ferromagnet.

Unit 4: Superconductivity **(8 hours)**

Electron-electron interaction via lattice: Cooper pairs; BCS theory; Bogoliubov transformation — notion of quasiparticles; Ginzburg-Landau theory and London equation; Meissner effect; Type II superconductors — characteristic length; Josephson effect; "Novel High Temperature" superconductors.

Unit 5: Superfluidity **(8 hours)**

Basic Phenomenology; Transition and Bose-Einstein condensation; Two fluid model; Roton spectrum and specific heat calculation, Critical velocity.

Unit 6: Disordered systems **(8 hours)**

Disorder in condensed matter — substitutional, positional and topographical disorder; Short- and long-range order; Atomic correlation function and structural descriptions of glasses and liquids; Anderson model; mobility edge; Minimum Metallic Conductivity, Qualitative application of the idea to amorphous semiconductors and hopping conduction

Unit 7: Selected topics **(5 hours)**

Mott transition and Hubbard Model, Kondo effect.

Reference Books:

- Condensed Matter Physics by Michael P. Marder, *John Wiley and Sons*
- Quantum Theory of Solids by C. Kittel, *John Wiley and Sons*
- Solid State Physics by Guiseppe Grosso and Guiseppe Pastori Parravicini, *Academic Press, The Elsevier Science*
- The Physics and Chemistry of Solids by Stephen Elliott, *John Wiley and Sons*
- Solid State Physics by Neil W. Ashcroft and N. David Mermin, *Haracourt College Publishers*
- Principles of Condensed Mater Physics by P. M. Chaikin and C. Lubensky, Cambridge University Press

<u>Course Articulation Matrix of PAS9114- Advanced Condensed Matter Physics-I</u>

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	1	3	3	3	1	2	2	1
CO2	3	1	2	2	1	2	1	3	3	1
CO3	1	1	3	1	1	3	2	1	1	3
CO4	3	1	1	2	2	1	3	3	3	2
			s							

1: **Partially related**
2: **Moderately related**
3: **Strongly related**

Plasma Physics-I

Course Code:PAS9117 **Course Type: Research Work (ES-1)**
Course Credit: 4
Course Objectives: *This course aimed at giving foundation course in Plasma Physics. Understanding the plasma state as distinct from other three states, developing concepts of Debye screening collective behavior, quasi neutrality. Deriving a set of fluid equations to study plasma properties, Using fluid equations to study plasma waves, equilibrium and stability, Understanding concepts of plasma resistivity, diamagnetism, paramagnetims.*

Course Outcomes: *This gives details about the Quantum Mechanics and Application courses offered for Master in Science (M Sc) course in the department of Physics and Astronomical Sciences. After getting this course the student will be acquainted with the basic principles Plasma Physics.*

CO1: *After getting this course the student will be acquainted with the basic principles Plasma Physics.*

CO2: *The students shall be able to understand fluid model of plasma system through fluid equations like Vlasov equation and Landau Damping.*

CO3: *Student shall be to understand electromagnetics of the plasmonic systems.*

CO4: *They will also be able to explain the propagation of electromagnetic waves and its different modes through the plasmonic systems.*

Course Contents

Unit-1: Occurrence of plasmas in nature, Definition of plasma, Concept of temperature In plasma, Debye shielding, The plasma parameter, Criteria for plasmas, Application of plasma physics: Gas discharge, Controlled thermonuclear fusion, Space physics, Modern astrophysics, MHD energy conversion and ion propulsion, Solid state plasmas, Gas Lasers

(10 hours)

Unit-2: Motion of Charged particles in electromagnetic field: Energy conservation, Motion of charged particle in uniform (i) electrostatic field (ii) magneto static field, Drift due to an external force.Kinetic pressure in a partially ionised gas, Basic concepts related to collision of particles in a plasma: collision cross section, mean free path, collision frequency, collision between charged particles, inelastic collisions: charge transfer, electron attachment, recombination.

(10 hours)

Unit-3: Motion of charged particle in non-uniform magnetic field: Spatial variation of the magnetic field: Divergence term, Gradient and curvature term, Shear term, Equation of motion in the first-order approximation, Average force over one gyration period: Parallel force, perpendicular force, total average force, Gradient drift, Parallel acceleration of guiding center: Invariance of the orbital magnetic moment and of the magnetic flux, Magnetic mirror effect, the longitudinal adiabatic invariant, Curvature drift, Combined Gradient and curvature drift, Time varying E field, Time varying **B** field, Adiabatic invariants.

(10 hours)

Unit-4: Degree of ionisation and Saha ionisation formula, Methods of plasma production: Classical Townsend mechanism and electrical breakdown of gases, Streamer mechanism and micro discharges, Electrical discharge (Arc discharge and glow discharge) Plasma diagnostics: High frequency current measurement (Rogowski coil), magnetic probe, Electric probes: single (Langumuir) probe, double probe, triple probe, emissive probe, Plasma spectroscopy (Line radiation and continuum radiation)

(10 hours)

Text books/Reference books:

1. F. F. Chen, Introduction to Plasma Physics and Controlled fusion (2/e), Springer, 2009.
2. J. A. Bittencourt, Fundamentals of Plasma Physics (3/e), Springer, 2013.
3. N. A. Krall and A. W. Travelpiece, Principle of Plasma Physics, San Francisco Press,(1/e) 1986.
4. R. J. Goldston and P. H. Rutherford, Introduction to Plasma Physics, Institute of Physics Publishing, (1/e) 1995.
5. Hans R. Griem, Principles of Plasma Spectroscopy, Cambridge University Press,(1/e) 1997.
6. R. H. Huddlestone and S. L. Leonard, Plasma Diagnostic Techniques, Academic Press,(1/e) 1965.
7. I. H. Hutchinson, Principles of Plasma Diagnostics, Cambridge University Press (2/e), 2005.

Course Articulation Matrix of PAS9117- Plasma Physics-I

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	3	3	2	1	1	3	3	3	3
CO2	2	2	3	1	1	2	1	1	2	3
CO3	3	1	3	2	1	3	1	3	1	1
CO4	3	3	3	2	2	1	3	3	2	3

1: **Partially related**
2: **Moderately related**
3: **Strongly related**

Particle Physics-I

Course Code:PAS9119 **Course Type: Research Work (ES-1)**
Course Credit: 4
Course Objectives:

An Overview of Elementary particle physics, Symmetry Principles, conservation laws and Quark Model, Feynman Calculus, QED, and QCD, Weak Interactions and Electroweak Standard Model, Physics Beyond the Standard Model.

Course Outcomes: After completion of the course the student will be able to explain:

CO1: *relativistic dynamics, especially in the context of multiparticle interactions.*

CO2: *The role of symmetries, both discrete and continuous in understanding particle interactions and their classification. SU(3) and quark model..*

CO3: *Based on observables, drawing up a theory of particle interactions, Fermi theory of beta decay.*

CO4: *Phenomenological understanding of quark and neutrino mixing and CP violation.*

CO5: *Microscopic derivation within the Standard Model.*

Course Contents:

Unit-1: Introduction and Dirac Equation **(5 hours)**

- Historical Introduction of Elementary particles, Classification, Quantum numbers & Conservation laws
- Four Forces, Range of Forces, Yukawa Potential, Zero Range Approximation
- Dirac Equation: High energy units, Antiparticles and Bilinear covariants

Unit-2: Symmetries and Quarks **(5 hours)**

- Symmetry, Group and Conservation laws, Translational and Rotational Invariance, Parity, Charge conjugation, Time reversal
- Combining Representations, Young's Tableaux, SU(2), SU(3) groups
- Quark Model

Unit-3: S- Matrix, Wick's Theorem and QED **(8 hours)**

- The S-Matrix expansion, Wick's theorem
- The Golden rule, The Feynman rules for a toy theory, Lifetime of the A,
- Feynman Rules for QED, Inelastic electron and muon scattering

Unit-4: QCD and Weak Interactions **(10 hours)**

- Structure of Hadrons, Partons and QCD
- Parity Violation and the V-A Form of the weak current, Interpretation of the Coupling G, Helicity of Neutrinos, Muon decay, Charged current neutrino-electron scattering, Neutrino-quark scattering, First observation of weak neutral currents,

- Neutral current, The Cabibbo Angle, Weak Mixing Angles, CP Violation: The Neutral Kaon System.

Unit-5: Electroweak Interactions, Standard Model and Beyond (12 hours)

- Electroweak theory, Lagrangian in particle physics, Weak spin, Gauge invariance, Standard Model Largrangian, U(1) terms, SU(2) terms, Neutral currents, Charged currents, Quark Lagrangian, Fermion gauge boson Lagrangian
- Standard model masses, Spontaneous symmetry breaking, Abelian Higgs mechanism, Higgs mechanism in the Standard Model
- Grand Unified Theories, Supersymmetry, Strings, etc...

Prescribed Textbooks:

1. Halzen, F. and Martin A.D.: Quarks and Leptons, John Wiley & Sons, 1984.
2. Gordon, Kane, Modern Elementary Particle Physics, Addison-Wesley Pub. Co. Inc. 1987.
3. Griffiths, D.: Introduction to Elementary particles, John Wiley & Sons.

Books for Further Reading

1. Martin, B.R. and Shaw, G: Particle Physics, John Wiley & Sons Ltd. 2009
2. A. Lahiri and P.B. Pal: A First book of quantum field theory, 2nd edn, Narosa publ. house.
3. Donald, H. Perkins: Introduction to High Energy Physics, Cambridge University Press.
4. Khanna, M.P.: Introduction to Particle Physics, PHI Learning Pvt. Ltd., New Delhi 1999.

Course Articulation Matrix of PAS9119- Particle Physics-I

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	2	3	1	2	2	1	2	1
CO2	1	3	2	2	1	2	3	1	3	1
CO3	1	3	1	1	3	2	3	3	3	1
CO4	3	2	1	2	1	1	1	1	2	3
CO5	3	3	2	2	2	1	2	2	2	1

1: Partially related
2: Moderately related
3: Strongly related

Theoretical Nuclear Physics

Course Code: PAS9113 **Course Type: Research Work (ES-1)**
Credits: 4

Course Objectives:
The course is designed to study the following, Interaction of nuclear radiation like charged particles, neutrons, gamma and positron with matter and how these radiations are detected. Study of decay laws, theory and use in the structure exploration of nuclei. Nuclear reactions, kinematics, reaction cross-sections, different types and theories developed. Nuclear Fission, characteristics and applications. Basic fusion process it characteristics, solar fusion etc.

Course Outcomes: After the completion of the course the student shall be able to explain:

CO1: *the ground state properties of the nucleus for study of the nuclear structure behaviour, the deuteron behaviour at ground and excited states.*
CO2: *Understand radioactive decay and interaction of the radiations with matter.*
CO3: *apply deuteron physics and the Nucleon-Nucleon scattering for explaining the nuclear forces.*
CO4: *the shell model and collective model descriptions.*
CO5: *apply various aspects of nuclear reactions in view of compound nuclear dynamics.*
CO6: *Understand basics of reactor technology.*

Course Contents

Unit 1: Interaction of nuclear radiation with matter **(10 hours)**

- Interaction of charged particles with matter
- Interaction of neutrons with matter: energy loss and energy distribution after collision
- Interaction of gamma radiation with matter: attenuation of gamma rays, Compton Effect, photoelectric effect and pair production.
- Interaction of positron with matter
- Detection of nuclear radiation

Unit 2: Radioactive Decay **(10 hours)**

- Radioactive decay law, Quantum theory of radiative decays, production and decay of radioactivity, Growth of Daughter activities.
- Alpha decay: energetic, decay constant, hindrance factors, alpha particle spectra
- Fermi theory of β-decay, Electron and positron energy spectra, electron capture decay, parity non conservation in β-decay, nuclear structure information from β-decay.
- Theory of γ-decay and internal conversion and nuclear structure information from γ-decay

Unit 3: Nuclear reactions **(12 hours)**

- Cross-sections, reciprocity theorem, Elastic scattering and method of partial waves, relationship between differential and scattering amplitude.
- Free particle, turning the potential on, scattering amplitude and elastic scattering cross-section, reaction cross-section.
- Scattering by simple potential, square well potential.
- Theory of resonance: General aspects, logarithmic derivative and cross-section, Breit-Wigner formula, R-Matrix theory.

Unit 4: Nuclear Fission and Fusion (8 hours)

- Fission: Characteristics of Fission, Energy In Fission, Fission and Nuclear Structure, Controlled Fission Reactions, Fission Reactors, Radioactive Fission Products, Fission Explosives.
- Basic fusion processes, characteristics of fusion and solar fusion.

Prescribed Text Books:

1. Introductory Nuclear Physics, K. S. Krane, John Wiley& Sons Ltd
2. An Introduction to Nuclear Physics, W. N. Cottingham, D. A. Greenwood, Cambridge University Pres

Other Resources/Reference books:

1. Fundamentals In Nuclear Physics from Nuclear Structure to Cosmology Jean-Louis Basdevant, James Rich, Michel Spiro, Springer
2. B.R. Martin, Nuclear and Particle Physics, John Wiley& Sons Ltd.
3. R.R. Roy and B.P. Nigam, Nuclear Physics: Theory and experiment, New age International (P) limited, Publishers.

Course Articulation Matrix of PAS9113- Theoretical Nuclear Physics

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	3	2	3	2	3	2	2	1	3
CO2	3	2	2	1	1	3	3	1	1	2
CO3	2	2	3	2	3	1	1	1	1	1
CO4	3	2	1	3	2	3	3	1	1	2
CO5	3	3	2	2	2	1	1	3	2	2
CO6	2	3	3	1	2	3	1	3	2	3

1: Partially related
2: Moderately related
3: Strongly related

Gravitation and Cosmology-I

Course Code: **PAS9118** **Course Type: Research Work (ES-1)**
Credits: 4
Course Objectives: *General theory of relativity is presently the accepted theory of classical gravity. It was created by Einstein in 1915 in an endeavor to extend the principles of special relativity for accelerated observers. This theory is considered the greatest scientific creation by any individual since the time of Newton. General theory of relativity has been*
applied everywhere with great success, be it in the stars (relativistic astrophysics), the universe (relativistic cosmology) or the GPS in your our mobile phone. A theory with such vast set of applications (and almost a hundred years old), we believe, is a must learn for students. The course is designed to introduce you to the fundamentals of the theory and it's application in understanding the geometry and spacetime structure of compact massive objects.

Course Outcomes: *The student will be able to:*
CO1: *Understand tensor algebra and tensor calculus on flat spacetimes.*
CO2: *Understand tensor algebra and calculus on curved spacetimes.*
CO3: *Develop understanding for relativistic gravitation theory.*
CO4: *Understand Einstein equations and their solutions at large and small scales.*
CO5: *understand gravitational waves.*

Course Content:

Unit 1: Newtonian gravity and special relativity **(5 hours)**

Basics of special relativity, Relativity in Four Vector Notation: Four-vectors, Lorentz Transformation and Invariant interval, Space-time diagrams. Proper time and Proper velocity. Relativistic energy and momentum - Four momentum. Newton's theory of gravity, The principle of equivalence, Non-inertial frames and non-Euclidean geometry; General coordinate transformations and the general covariance of physical laws.

Unit 2: Geometry of curved spacetime **(10 hours)**

Contravariant and covariant vectors; Tangent vectors and 1-forms; Tensors: product, contraction and quotient laws; Wedge product, closed forms; Levi-Civita symbol; Tensor densities, the invariant volume element. Parallel transport and the affine connection; Covariant derivatives; Metric tensor, raising and lowering of indices; Christoffel connection on a Riemannian space; Geodesics; Space-time curvature; Curvature tensor; Commutator and Lie derivative; Equation for geodesic deviation; Symmetries of the curvature tensor; Bianchi identities; Isometries and Killing vectors. Energy- momentum tensors and conservation laws.

Unit 3: Einstein's field equations **(10 hours)**

Einstein's tensor and the Einstein equation. The Einstein equations with matter and cosmological constant. Einstein's equations from an action principle: (i) The action for gravity and it's variation (ii) The action for matter and electromagnetic fields. Linearlised approximation, Gauge freedom of linearised perturbations, Gauge independent degrees of freedom, wave equation for gravity. Newtonian approximation of GR.

Unit 4: Compact objects and experimental tests of GR (15 hours)

Static, spherically symmetric space-time; Schwarzschild's exterior solution; Motion of perihelion of Mercury; Bending of light; Gravitational red shift. Radar echo delay. Schwarzschilds interior solution; Tolman-Oppenheimer-Volkov equation; Collapse of stars, Chandrasekhar limit and its derivation, formation of white dwarfs, neutron stars and supernovae, Black holes and their properties.

Unit 5: Black Holes (10 hours)

Black hole spacetimes: Coordinate and spacetime singularities. Eddington-Finkelstein, Kruskal-Szekeres and Painleve- Gulstrand coordinates. Penrose diagrams. Reissner-Nordstrom metric, Kerr metric; Ergosphere; Kerr-Newman metric.

Unit 6: Cosmology (10 hours)

The Weyl postulate and the cosmological principle. The Friedmann- Robertson-Walker spacetime. Kinematics of FRW spacetime, redshifts, luminosity distance. Dynamics of FRW spacetime: Open, closed and flat universes. Models of the universe. Big bang theory, Flatness, horizon, and relic abundance problems; and inflationary and the slow-roll models. Thermal history of the early universe, Cosmic microwave background radiation, its isotropy and anisotropy properties; COBE, WMAP and Planck experiments; CMBR anisotropy as a hint to large scale structure formation;

Text books:

1. S. Weinberg: Gravitation and Cosmology
2. P.A.M. Dirac: General Theory of Relativity
3. L. Landau and E. M. Lifshitz: Classical theory of fields, Pergamon.
4. V. Mukhanov: Physical Foundations of Cosmology.

Reference Books:

1. J.V. Narlikar: Introduction to Cosmology, Cambridge.
2. J. Hartle- Gravity, Pearson, (2000).
3. N. M. J. Woodhouse- General relativity, Springer (2000).
4. E. Taylor and J. Wheeler: Spacetime physics, W.H. Freeman (1992).
5. E. Taylor and J. Wheeler: Exploring black holes, Addison Wesley (2000).
6. B. Schutz: A first course on general relativity, Cambridge Univ. press, (2009).

7. Einstein: The special and the general theory, Empire books, (2013).
8. S. Chandrasekhar: An introduction to stellar structure, Cambridge Univ. press.
9. R. d'Inverno: Introducing Einstein's relativity, Oxford Univ. press (1992).
10. A. Liddle: An Introduction to Modern Cosmology
11. C.W. Misner, K.S. Thorne and J.A. Wheeler: Gravitation
12. R.M. Wald: General Theory of Relativity, Chicago university press.

Course Articulation Matrix of PAS9118- Gravitation and Cosmology-I

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	3	2	3	2	3	2	3	3	3
CO2	1	3	2	2	3	1	2	3	2	3
CO3	1	3	1	3	1	1	2	3	2	1
CO4	1	3	2	2	1	3	1	2	3	2
CO5	2	2	3	3	3	1	1	1	1	3

1: Partially related
2: Moderately related
3: Strongly related

Vocational and Skill Based Courses

Programming in python

Course Code: PAS8106L **Course Type: Vocational/Skill**
Credits: 2
Course Objectives: *Proficiency in computer programming/coding has arguably become one of the most important skills a researcher needs in science today. There are a number of reasons for this, prime among them is, as a consequence of advances in tools and technology, researchers/post-graduate are now collecting and working with larger datasets. These datasets require computing coding and machine learning steps for carrying out efficiently an unbiased and large-scale analysis. There are many ways to learn how to code and it is important to identify the method that works best for your science project. First, you have to decide which computer language you are going to learn. A few of the bigger and recommended languages for science include Python, IDL, R, c++ etc. Among them, Python being both open sources as well as an interpreted language having so many packages in builts is commonly preferred in the present scenario.*

Learning Outcomes: *After completing the course satisfactorily, a student will be able:*

CO1: *To understand the technique in observational astronomy*
CO2: *To understand the distance ladder in the context of the size of the Universe*
CO3: *To understand the basic syntax of python*
CO4: *The use of importing library in python*
CO5: *Plotting techniques using the various python library*
CO6: *Use of numpy and astropy to illustrate python capability in array operation*
CO7: *Python library for matrices operation*
CO8: *Learn to use the various routines in scientific projects consisting of various parameter optimizations techniques.*

Course Contents:

Unit 1: Introduction, Using Code Examples How to Run Python Code, A Quick Tour of Python Language Syntax . **(5 Lectures)**

Unit 2: Basic Python Semantics: Variables and Objects, Basic Python Semantics: Operators Built-In Types: Simple Values, Built-In Data Structures, Control Flow . **(5 Lectures)**

Unit 3: Defining and Using Functions Errors and Exceptions Iterators, List Comprehensions, Generators . **(5 Lectures)**

Unit 4: Modules and Packages, String Manipulation and Regular Expressions, A Preview of Data Science Tools . **(5 Lectures)**

Unit 5: Finally, a basic query for data mining from large science experiments and surveys (e.g in astronomical sciences), based on mysql and php programming, optimized by a set of constraints by taking some examples of research projects, will also be covered. For further advancement, a few examples by using codes publically available in GitHub repository which are also relevant for the area of research being pursued at the university will be discussed by using them as subroutines in our planned main codes, so as to learn their use to carry out an unbiased and large-scale analysis of large datasets exist in various public archives. **(10 Lectures)**

Prescribed Text Book:

1. A Whirl Wind Tour of Python, by Jake Vande Plas.

Course Articulation Matrix of PAS8106L- Programming in Python

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	3	3	1	3	3	2	1	3
CO2	3	2	3	1	2	3	2	1	1	1
CO3	2	2	2	3	3	1	3	1	2	2
CO4	2	2	3	1	1	3	3	3	1	2
CO5	2	1	2	2	2	1	1	2	2	1
CO6	3	1	2	1	1	1	1	1	1	3
CO7	2	2	3	2	1	1	3	3	1	3
CO8	1	1	2	1	2	3	1	3	2	3

1: Partially related
2: Moderately related
3: Strongly related

Nuclear Radiation and Safety

Course Code: PAS92XX **Course Type: Vocational/Skill**
Credits: 2
Course Objectives: *The main aim of this course is to make you aware and understand the radiation hazards and safety. Students renew and expand their knowledge on nucleus and atom structure, and get basis of: different kinds of radioactive transformations, interactions of radiation with matter and its effects on living cells, detection of different kind of radiation, procedures of handling with radiation sources and applying radiation protection, basic knowledge of national and international legislation and recommendations in radiation protection. Students will become capable to implement the fundamental knowledge into everyday life and to critically consider benefits and risks of radiation.*

Course Outcomes: After the completion of the course, the student will be able to:
CO1: *Understand the consequences of poor safety with regard to handeling radioactive sources and nuclear radiations, in general.*
CO2: *Be aware of and understand the key factors influencing the basis for nuclear safety.*
CO3: *Understand the hazards associated with nuclear plant and how risks can be controlled.*
CO4: *Get required to work in a radiation prone allied research fields.*

Course Contents

Unit 1: Basics of Atomic and Nuclear Physics: Basic concept of atomic structure; X rays characteristic and production; concept of bremsstrahlung and auger electron, The composition of nucleus and its properties, mass number, isotopes of element, spin, binding energy, stable and unstable isotopes, law of radioactive decay, Mean life and half life, basic concept of alpha, beta and gamma decay, concept of cross section and kinematics of nuclear reactions, types of nuclear reaction, Fusion, fission. **(7 Lectures)**

Unit 2: Interaction of Radiation with matter: Types of Radiation: Alpha, Beta, Gamma and Neutron and their sources, sealed and unsealed sources, Interaction of Photons - Photoelectric effect, Compton Scattering, Pair Production, Linear and Mass Attenuation Coefficients, Interaction of Charged Particles: Heavy charged particles - Beth-Bloch Formula, Scaling laws, Mass Stopping Power, Range, Straggling, Channeling and Cherenkov radiation. Beta Particles- Collision and Radiation loss (Bremsstrahlung), Interaction of Neutrons- Collision, slowing down and Moderation. **(7 Lectures)**

Unit 3: Radiation detection and monitoring devices: Radiation Quantities and Units: Basic idea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, Annual Limit of Intake (ALI) and derived Air Concentration (DAC). Radiation detection: Basic concept and working principle of gas detectors (Ionization Chambers, Proportional Counter, Multi-Wire Proportional Counters (MWPC) and Geiger Muller Counter), Scintillation Detectors (Inorganic and Organic Scintillators), Solid States Detectors and Neutron Detectors, Thermo luminescent Dosimetery. **(10 Lectures)**

Unit 4: Radiation safety management: Biological effects of ionizing radiation, Operational limits and basics of radiation hazards evaluation and control: radiation protection standards, International Commission on Radiological Protection (ICRP) principles, justification, optimization, limitation, introduction of safety and risk management of radiation. Nuclear waste and disposal management. Brief idea about Accelerator driven Sub-critical system (ADS) for waste management. **(6 Lectures)**

Prescribed Text Books:

1. Introductory Nuclear Physics, K. S. Krane, John Wiley& Sons Ltd
2. An Introduction to Nuclear Physics, W. N. Cottingham, D. A. Greenwood, Cambridge University Pres.
3. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
4. Elements of Nuclear Physics, Walter E. Meyerhof, McGraw-Hill Book Company.

Course Articulation Matrix of PAS92XX- Gravitation and Cosmology-I

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	3	1	3	1	3	1	2	2	3
CO2	2	1	3	3	1	1	2	2	1	1
CO3	3	2	3	1	3	1	1	2	3	3
CO4	2	3	2	1	2	3	3	1	3	1

1: Partially related
2: Moderately related
3: Strongly related

Practical: General Physics

Course Code: PASPAS8105L **Course Type: Vocational/Skill**
Credit: 2
Course Objectives: *The course is designed to perform experiments and simulations to go hand in hand with the theory courses on Classical Mechanics and Electro-Dynamics , All the experiments shall be based on two techniques, Video Motion Based Analysis using Tracker, Data Acquisition using Expeyes kit. All the simulations shall be performed in Scilab.*

Course Outcomes: *By the end of the three-course intro lab sequence, students should be able to:*
CO1: *Collect data and revise the experimental procedure iteratively, reflectively, and responsively.*
CO2: *Evaluate the process and outcomes of an experiment quantitatively and qualitatively*
CO3: *Extend the scope of an investigation whether or not results come out as expected*
CO4: *Conduct an experiment collaboratively and ethically*

List of Experiments:

Lab 1: Simple Pendulum Experiment for small and large angle oscillations
- Introduction to Video Analysis using Tracker.
- Importance of matching the experimental outcomes with theoretically expected results.
- Extension: to study damped harmonic oscillator
- Simulation of the experiment using xcos in Scilab

Lab 2: Coupled Oscillator Experiment
- Normal mode oscillations
- Transfer of energy between the two oscillators
- Determination of g by varying the height of coupling between the oscillators
- Simulation of the experiment using xcos in Scilab

Lab 3: Double Mass Spring System/Double Pendulum
- Obtaining the frequencies of the system and comparision with the theoretically expected result.
- Simulation using xcos in Scilab

Lab 4: Variable Mass-spring system
- To determine the rate of loss of sand with increasing hole size
- To determine the variation in amplitude w.r.t. to rate of loss of mass, for different hole sizes
- Simulation using xcos

Lab 5: Fourier Analysis using Electrical and Electronic circuits
- Obtain the fourier components and co-efficients of a square wave using a LCR circuit
- Obtain the fourier components and co-efficients using op-amp filter circuits

Lab 6: Verification of Fresnel's Equations

- Production and Analysis of linearly and circularly polarised light
- Angular dependence of reflection and transmission
- To explore Brewster's law and find Brewster angle

Lab 7: Dielectric constant of liquids using Colpitts oscillator

Lab 8: Zeeman Effect

Lab 9: Magnetic Susceptibility of a paramagnetic liquid

Reference: Departmental Lab Manuals.

Course Articulation Matrix of PAS8105L- General Physics Lab

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	3	3	3	2	2	3	1	3
CO2	2	1	2	3	2	1	1	1	1	1
CO3	1	3	2	3	3	3	1	1	2	2
CO4	1	2	3	3	2	3	2	2	1	1

1: Partially related
2: Moderately related
3: Strongly related

Computational Physics Laboratory

Course Code: **PAS8206L** **Course Type: Vocational/Skill**
Course Credit: 2

Course Objectives: *The students will be exposed to the basic working of computer in the context of modelling some simple systems. To understand the logical structure of the problem and its implementation on the computer. It, also, includes the use of basic mathematical and numerical techniques in computer calculations leading to solutions for typical physical problems.*

Course Outcomes;
After the completion of the course, student shall be able to:
CO1: *develop a logical way of implementing the constraints of the given physical system and transforming them into a numerical code.*
CO2: *They will be able to numerically solve the equations of motions of some simple systems. In this way they will be able to understand the requirement of a good code and the things required to make it more accurate and time efficient.*

Statistical Mechanics Simulations:

Worksheet based Simulations:

Lab 1: Microstates, Macrostates and Steady-state equllibrium
Lab 2: Ergodic Hypothesis Demonstration

Simulations in Scilab:

Lab 3: Boltzmann Distibution: P(E) vs E
Lab 4: Boltzmann Speed Distribution and Maxwell's velocity distribution
Lab 5: Joule's Expansion and Entropy

Quantum Mechanics Simulations:

Lab 6: Solving the Time-Dependent Schrodinger Equation and obtaining the spreading of Gaussian wavepacket
Lab 7: Studying the Scattering of Gaussian wavepacket
Lab 8: Scattering from a step potential and a barrier potential

Manuals will be provided during the lab sessions.

Course Articulation Matrix of PAS8206L- Computational Physics Lab

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	1	1	2	1	1	1	1	2
CO2	3	3	3	1	3	1	1	2	2	3

1: Partially related
2: Moderately related
3: Strongly related

Semiconductor Devices

Course Code: PAS9XXX **Course Type: Vocational/Skill**

Course Credit: 2

Course Objectives:

Applications in solving problems of interest to physicists. Explore the potential application of semiconducting devices.

Course Outcomes:

CO1: *Explains the working principle of a p-n junction.*

CO2: *Describes electronic behavior of a diode in a circuit.*

CO3: *Explains current-voltage characteristics of a diode under forward and reverse bias.*

CO4: *Explains the working principle of a junction transistor.*

CO5: *Explains the behavior of carriers in a junction transistor.*

CO6: *Explains current-voltage characteristics in a field effect transistors.*

CO7: *Explains the working principle of a metal oxide field effect transistor.*

CO8: *Explains how the metal-semiconductor contacts will occur.*

CO9: *Defines the ohmic and Schottky contact.*

Course Contents

Unit 1: Semiconductor Materials **(4 Hours)**

- Charge Carriers in Semiconductors
- Dopant Atoms & Energy levels
- The Extrinsic Semiconductors
- Statics of Donors & Acceptors
- Charge Neutrality

Unit 2: Carrier Transport in Semiconductors **(6 Hours)**

- Carrier Drift (Drift Current, Mobility, Conductivity)
- Carrier Diffusion (Diffusion Current Density, Total Current Density)
- Graded Impurity Distribution (Induced Electric Field, The Einstein Relation)
- Carrier Generation and Recombination
- Characteristics of Excess Carrier
- Ambipolar Transport

Unit 3: The p-n Junction **(4 Hours)**

- Basic Structure of the pn Junction

- Zero Applied Bias
- Reverse Applied Bias
- pn Junction Current
- Small-Signal Model of the pn Junction
- Generation-Recombination Current
- Junction Breakdown

Unit 4: The Bipolar Transistor **(3 Hours)**

- The Bipolar Transistor Action
- Minority Carrier Distribution
- Low Frequency Common-Base Current

Unit 5: Metal-Semiconductor Junction: **(3 Hours)**

- The Schottky Barrier Diode
- Metal-Semiconductor Ohmic Contacts
- Heterojunctions

Prescribed Textbooks:

1. Semiconductor Physics & Devices, D. A. Neamen, Mc Graw Hill (2003).
2. Semiconductor Device Physics and Technology, S.M Sze, Wiley (1985).

Other Resources/Reference books:

1. Introduction to Semiconductor Devices, M. S. Tyagi, John Wiley & Sons.
2. The Physics of Semiconductor Devices, D.A. Eraser, Oxford Physics Series (1986).
3. Semiconductor Devices: Basic Principles, Jasprit Singh, Wiley (2001).

Course Articulation Matrix of PAS9XXX- Semiconductor Devices

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	1	2	3	3	1	3	1	2
CO2	3	3	3	1	1	2	2	3	1	1
CO3	3	3	1	1	2	1	2	2	2	1
CO4	2	3	2	2	2	3	2	1	3	1
CO5	1	1	1	1	2	2	2	2	2	2
CO6	1	3	1	1	2	2	2	3	1	1
CO7	1	2	3	3	1	1	2	2	2	3
CO8	1	3	3	3	3	2	1	1	2	3
CO9	3	3	2	2	2	3	1	1	3	2

1: Partially related
2: Moderately related
3: Strongly related

Interdisciplinary Courses

(IDC)

Mathematical Techniques

Course Code: PAS8103 **Course Type: IDC Major**
Course Credit: 2

Course Objectives:
The course aims to familiarize students to, Matrices, determinants and linear systems, Vector differential calculus, Complex numbers and functions Complex integration

Course Outcomes:
This gives details about the Mathematical Techniques offered for Master in Science (M Sc) course in the department of Physics and Astronomical Sciences. After getting this course the student will be acquainted with the basic principles Mathematical Techniques.
The students will have understanding of:
CO1: *Basic and advanced mathematical tools required for Physics Problems.*
CO2: *Different Techniques to solve differential and integral equations.*
CO3: *Various special functions and important transforms and their applications*
CO4: *They will understand (i) Complex analysis and integration. Also, knowledge shall be gained in areas like (i) Linear Vector Space and operator algebra, (ii) matrix diagonalization and series of matrices,and (iii) Green's functions.*

Course Contents

Unit 1: Matrices and their applications-I **(4 hours)**
- Matrices and their operations, linear transformations, special matrices, orthogonal and unitary matrices.
- System of linear equations, augmented matrix, rank of matrix,
- Gauss elimination and Gauss Jordan methods.
- Linear dependence of vectors and *n*-dimensional space, orthonormal basis and Garm-Schmidt method.

Unit 2: Matrices and their applications-II **(4 hours)**
- Matrix eigenvalues, eigenvectors of a matrix, Cayley-Hamilton theorem.
- Theorems about eigen values and applications.
- Coordinate transformations and matrices. Linear and similarity transformations.
- Diagonalization of matrices.

Unit 3: Complex numbers and functions **(4 hours)**
- Complex numbers and complex plane, Polar form of complex number, roots,
- Derivative and analyticity, Cauchy-Riemann equations,
- Analyticity and Laplace's equations.
- Complex form of exponential, trigonometric, hyperbolic and logarithmic functions.

Unit 4: Complex integration-I **(4 hours)**
- The line integral in a complex plane, ML inequality, Cauchy's integral theorem
- Cauchy's integral formula, n-th order derivatives of analytical function, Cauchy's inequality

- Power, Taylor, Maclaurin and Laurent series, Radius of convergence

- Singularities and zeros, Zeros of an analytical function.

Unit 5: Complex integration-II **(4 hours)**

- Laurent series and Residue integration method.
- Calculating residues
- Residue theorem.
- Applications of residue theorem to solve integrals in complex plane.

Prescribed Textbooks (Key texts):

1. Mathematical Methods for Physicists by G. Arfken and H.J. Weber , Elsevir Academic Press
2. Mathematical Methods in the Physical Sciences by W.L. Baos, John Wiley & Sons

Other Resources/Reference books:

1. Advanced Engineering Mathematics by Erwin Kreyszic, John Wiley & Sons
2. Explorations in Mathematical Physics: The Concepts Behind an Elegant Language by Don Koks, Springer Science
3. Mathematical Physics by B.S. Rajput, Pragti Prakashan
4. Mathematical Methods in the Physical Sciences by W.L. Baos, John Wiley & Sons
5. Advanced Engineering Mathematics by Peter V. O'Neil, Thomson

<u>Course Articulation Matrix of PAS8103- Mathematical Techniques</u>

COs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	3	3	2	1	3	3	3	3
CO2	3	2	1	3	3	3	2	2	1	2
CO3	2	1	2	3	1	3	1	2	2	1
CO4	2	2	2	3	2	3	1	2	1	2

1: Partially related
2: Moderately related
3: Strongly related