Course Contents
1st Semester
M.Sc. Physics

Classical Mechanics

Course Code: PAS 401A **Course Type: Core Compulsory**
Course Credits: 4
Course Objectives:

Understanding the concepts of classical mechanics which serves as a springboard for the various branches of modern physics; Lagrangian and Hamiltonian formulations of the dynamical systems; Hamilton Jacobi theory and the principle of least action provide the transition to wave mechanics while Poisson brackets and canonical transformations are invaluable in formulating the quantum mechanics.

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.

Classical Electrodynamics

Course Code: PAS– 403A **Course Type: Core-Compulsory**

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 behavior 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 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 generalization;

- 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

Quantum Mechanics

Course Code:PAS 404 A **Course Type: Core Compulsory**
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 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

- 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. G. Aruldhas, Quantum Mechanics, PHI Learning, Eastern Economy Edition 2013.
2. W. Greiner, Quantum Mechanics-An Introduction, Springer-Verlag, Germany.
3. David J. Griffiths, Introduction to Quantum Mechanics, Pearson Prentice Hall, Inc.

Other Resources/Reference books:

1. Ashok Das, Quantum Mechanics, Tata McGraw Hill (2007).
2. Leonard. I. Schiff, Quantum Mechanics, 3rd edition, Tata McGraw-Hill 2010.
3. J.J. Sakurai, *Modern Quantum Mechanics*, Addison-Wesley ISBN 0-201-06710-2).
4. R. Shankar, Principles of Quantum Mechanics, Second edition, Plenum Press, New York.
5. E. Marzbacher, Quantum Mechanics, Wiley Student Edition, 2011.
6. Mathews and Venkateshan, Quantum Mechanics, Tata McGraw-Hill 2010.
7. P.A.M. Dirac, The Principles of Quantum Mechanics, Snowball Publishing.
8. A. Messiah, Quantum Mechanics, Dover Books on Physics.

General Physics Laboratory

Course Code: PAS 413 **Course Type: Core Compulsory**
Course 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.

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.

Mathematical Physics

Course Code: PAS 402 **Course Type: Core Open**
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 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

3rd Semester
M.Sc. Physics

Condensed Matter Physics

Course Code: PAS 408A **Course Type: Core Compulsory**

Credit: 4

Course Objectives:

The course aims to introduce students to the internal architecture of materials to explore phenomena happening in materials at atomistic length scales.

Course Contents

Unit 1: Crystal Structure and Reciprocal Lattice (10 hours)

- Review of basic concepts in crystalline solids, periodic array of atoms
- Lattice, basis and crystal structure, unit cell, primitive lattice cell crystallographic planes and Miller indices.
- Symmetry operations, the seven crystal systems and Bravais lattices, point and space groups,
- Schoenflies and International notations. Illustration of some crystals such as NaCl, CsCl, Diamond structure, HCP and honeycomb lattice, Cubic ZnS, Perovskite structure.
- Diffraction of waves by crystals, Bragg's law
- Scattered wave amplitude, Fourier analysis, Reciprocal lattice vectors, diffraction conditions Laue equations.
- Brillouin zones. Wigner-Seitz cell and Ewald's construction.
- Structure factors and atomic form factors. Quasicrystals.
- Experimental methods of crystal structure determination: Laue, rotating crystal and powder method,
- Basics of electron and neutron diffraction by crystals.

Unit 2: Crystal Binding, Elastic Constants And Atomic Vibrations (12 hours)

- Continuum model and analysis of elastic strains, Elastic compliance and stiffness constants
- Elastic waves in cubic crystals: Longitudinal and transverse waves.
- Different types of binding forces for atoms in materials, cohesive energy
- Lenard-Jones potential and crystals of inert gases
- Ionic crystals and Madelung constant,
- Covalent and metallic crystals, hydrogen bonding. Atomic and ionic radii. Bulk modulus.
- Failures of static lattice approximation. Classical theory of Harmonic crystals: Harmonic and adiabatic approximations, Specific heat
- Vibrations of 1D crystals with mono atomic basis
- di and poly atomic basis Acoustical and optical phonon branches. Vibrations in 3D lattices.

- Phonon momentum, inelastic scattering by phonons.
- Quantum theory of Harmonic crystals: low and high temperature specific heat, Einstein and Debye models for phonon heat capacity.
- Phonon density of states. Anharmonic crystal interaction, thermal expansion, thermal conductivity of phonon gas, Normal and Umklapp processes.

Unit 3: Electron Gas: Free Electron Gas And Electrons In Lattice **(14 Hours)**

- Brief review of Drude model, Sommerfeld theory of metals, Fermi Dirac distribution function and effect of temperature on FD distribution function
- Free electron gas in three dimensions, electronic density of states. Fermi energy, momentum.
- Heat capacity of electron gas, heavy fermions. Electrical conductivity and Ohm's law.
- Motion of electron in magnetic fields: Hall effect.
- Thermal conductivity of metals and Wiedemann Franz law.
- Failures of free electron theory, electron in periodic potential. Nearly free electron model: origin and magnitude of band gap, Bloch's theorem.
- Born-Von Karman boundary conditions. Wave equation of electrons in a periodic potential: crystal momentum, central equation
- Kronig-Pennney model in reciprocal space,
- Empty lattice approximation, approximate solution near zone boundary.
- Density of states and van-Hove singularity.
- Extended, periodic and reduced zone schemes. effective mass of electron and concept of holes
- Tight binding method
- Band structures of some materials (Cu, Si, GaAs, NaCl).
- Fermi surfaces and their determination dHvA effect.

Unit 4: Superconductivity And Magnetism **(12 Hours)**

- Superconductivity: Introduction; experimental facts, zero resistivity, critical temperature, critical B field and critical current.
- Type-I and type-II superconductors, vortex state. Basic properties of superconductors: Isotope effect, Specific heat, Meissner effect,
- Thermodynamic properties; London equations
- Basic elements of BCS theory, Flux quantisation in superconducting ring, High temperature superconductors.
- Magnetism: Magnetization of matter and classification of magnetic materials. Diamagnetism and Langevin theory of diamagnetism.
- Paramagnetism: Langevin theory and Curie law for Paramagnetism,
- Weiss theory of Paramagnetism and Curie-Weiss law,
- Pauli Paramagnetism. Quantum theory of Paramagnetism: Effective number of Bohr magneton, Brillouin function.

- Ferromagnetism, ferromagnetic Curie temperature, exchange interaction, mean field approximation.
- Brief idea of Heisenberg model, magnons: Bloch $T^{3/2}$ law.
- Magnetic domains and domain theory, Bloch wall. Superparamagnetism.
- Ferrimagnetism: Curie temperature and Susceptibility. Antiferromagnetism: Neel temperature.

Prescribed Textbooks:

1. Introduction to Solid State Physics, C. Kittel, Wiley 8th edition
2. Solid State Physics, N. W. Ashcroft and N.D. Mermin, Cengage Learning
3. Solid State Physics, S.O. Pillai, New Age International

Other Resources/Reference Books:

1. Solid State Physics, Guiseppe Grosso and Guiseppe Pastori Parravicini, Academic Press
2. Solid State Physics, A. J. Dekker, Prentice Hall
3. Understanding solids: The science of materials, Richard J. D. Tilley, John Wiley and Sons

Nuclear and Particle Physics

Course Code:PAS 409A **Course Type: Core Compulsory**
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 nonconservation 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.

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.

Atomic, Molecular and Laser Physics

Course Code: PAS 411A Course Type: Core Compulsory Course Credit: 4

Course Objectives:

The course is designed to, discuss various aspects of atomic, and molecular spectra, Understand about Lasers and their applications to non-linear optics

Course Contents

Unit 1: Interaction of Radiation with Matter (4 hours)

- Electromagnetic spectrum, Spectrometers and experimental considerations
- Classical and Quantum Mechanical explanation of Micro-wave, IR and Raman Spectroscopy
- Time-dependent perturbation theory of radiation-matter interations
- Selection rules for one-photon transitions

Unit 2: Atomic Spectra (6 hours)

- Hydrogen like Spectra, Spin—Orbit Coupling
- Variational Principle, Hamiltonian for many electron system and Born-Oppenheimer Approximation
- Hartree Theory for He atom
- Hartree-Fock method for excited state of He atom
- Angular Momentum Coupling in Many-Electron Atoms
- Many-Electron Atoms: Selection Rules and Spectra
- The Zeeman Effect

Unit 3: Rotation and Vibrational Spectra in Diatomics (5 hours)

- Diatomic Rotational Energy Levels and Spectroscopy
- Vibrational Spectroscopy in Diatomics
- Vibration—Rotation Spectra in Diatomics
- Centrifugal Distortion
- The Anharmonic Oscillator

Unit 4: Electronic Spectra in Diatomics (5 hours)

- LCAO—MO Wave Functions in Diatomics
- Molecular Orbital Theory of Hydrogen molecule
- Electronic Spectra in Diatomics
- Flouroscence Spectroscopy
- NMR and ESR

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

- General Features and Properties
- Methods of obtaining Population Inversion
- Ray tracing in optical cavities; ABCD law;
- Stability diagram; ray tracing in stable cavity;
- Rate equations for two, three and four level laser systems;
- Spatial and temporal coherence;
- Longitudinal and transverse modes in laser cavities – concepts;
- Q-Switching and Mode Locking

Unit 6: Types of Lasers **(4 hours)**

- Solid-state lasers (Ruby, Nd-YAG)
- Gas Lasers (He-Ne, CO2)
- Semi-conductor lasers
- Ion Lasers (Argon ion and Krypton ion)
- Dye lasers

Unit 7: Laser Spectroscopy **(8 hours)**

- Raman Spectroscopy
- Photoluminiscense process
- Non-linear Optics

Prescribed Textbooks:

1. Jeanne L. McHale, "Molecular Spectroscopy" First Edition, Pearson, 2009.
2. J. Michael Hollas, "Modern Spectroscopy" Fourth Edition, Wiley, 2013.
3. A. K. Ghatak and Thyagarajan, "Optical Electronics", Cambridge University Press, 1989.
4. Amnon Yariv, :Quantum Electronics", John Wiley & sons, 1987.
5. Verdeyan, Laser Electronics, Prentice Hall, 1995.

Other Resources/Reference books:

1. Walter S. Struve, Fundamentals of Molecular Spectroscopy, John Whiley and Sons, 1989.
2. Michael R Muller, "*Fundamentals of Quantum Chemistry: Molecular Spectroscopy and Modern Electronic Structure Computations*", 1st Edition, Springer, 2001.
3. Elaine M. McCash, Colin N. Banwell, "Fundamentals of Molecular Spectroscopy", 5th Edition, Mc-Graw Hill Education, 2013.
4. G. Aruldhas, *Molecular Structure and Spectroscopy, 2nd Edition,* PHI Learning, 2009.
5. J Michael Hollas, *Basic Atomic and Molecular Spectroscopy*, Royal Society of Chemistry, 2002.
6. Straughan, B. P. and Walker, S. : Spectroscopy: (Vols. 1 - 3), Chapman and Hall (1976).
7. Chang, R. : Basic Principles of Spectroscopy, McGraw Hill (1971).
8. Characterization of Materials, E. N. Kaufmann, Wiley (2003).

Quantum Field Theory

Course Code:PAS 426A **Course Type: Elective**

Specialization 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 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).

Modern Physics Laboratory

Course Code: PAS 423 **Course Type: Core Compulsory Course**
Credit: 2

Course objectives:

The course is designed to perform experiments to go hand in hand with the theory courses on Condensed Matter Physics, Nuclear physics and Atomic, Molecular and Laser physics

Experiments:

Lab 1: Four Probe Method

- Measurement of resistivity of a semiconductor by four-probe method at different temperature and determination of band gap.

Lab 2: Hall Effect

- Determination of Hall coefficient of a given semiconductor and estimation of charge carrier concentration.

Lab 3: Experiments using Geiger-Muller Counter

- Characterization of GM tube
- Nuclear counting statistics

Lab 4: Experiments using Gamma-ray spectrometer

Lab 5: Experiments using Alpha spectrometer

- Prepare the radioactive source using electrolysis for thin film decomposition
- Obtain the alpha spectrum and analyze

Lab 6: Zeeman Effect

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

Lab 7: Michelson Interferometer

Lab 8: Electron Spin Resonance

Lab 9: Laser Beam Parameters

- Determine the wavelength of laser
- Determine the laser beam waist and beam spreading
- Determine the coherence length of laser

Reference: Lab Manuals of CUHP.

Modeling and Simulation

Course Code: CSI 411 **Course Type: Elective Open**

Course Credit: 2

Course Objectives:

To introduce students to, Electronic structure calculations using Free Open Source Software (FOSS) Elk, Molecular simulations using FOSS Games

Lab 1: Ground State energy calculations for single atom crystals

- Aluminium in Simple Cubic, BCC and FCC structures

Lab 2: Ground State energy calculation for various elements in diamond structure

- Silicon
- Germanium
- Carbon

Lab 3: Ground state energy calculation for determining the HCP structure

Lab 4: Density of States and Band Structure calculations

- Si, Ge, GaAs, ...

Lab 5: Magnetic properties of simple elements like Fe, Co, Ni,etc

Lab 6: Study of Diatomic molecules using Gamess

- Determination of potential energy curve as a function of bond distance for various diatomic molecules like H2, HCl, etc.
- Obtain the equilibrium bond length, vibrational frequencies and bond strength for each of the molecules.

Lab 7: Study of tri-atomic molecules using Gamess

- Determination of potential energy curve as a function of bond distance and bond angle for triatomic molecules CO2 and H2O
- Obtain the equilibrium bond length, vibrational frequencies and bond strength for each of the molecules.

Lab 8: Study of NH_3 and CH_4 molecules using Gamess

- Determination of potential energy curve as a function of bond distance for various diatomic molecules like H2, Hcl, etc.
- Obtain the equilibrium bond length, vibrational frequencies and bond strength for each of the molecules

Human-Making Courses to be offered by the Department

Sr. No.	Course Code	Course Name	Credit
1	PAS 417 A	History and Philosophy of Science	2

B.Sc. (Physics/ Honours)

1st, 3rd, 5th Semester

The course contents will be as per given in the UGC guidelines at:

https://www.ugc.ac.in/ugc_notices.aspx?id=1077

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