Syllabus

First Semester Courses in MSc (Physics)

2023-2024

Contents:

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APPROVED SYLLABUS

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ST. XAVIER'S COLLEGE
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Syllabus

First Semester Courses in MSc (Physics)

2023-2024

Contents:

MSc-I (Physics) Course Code: PSPHY6001CR1

Mathematical Physics

Credits: 4 (Theory 3 - Total 45 hours, Practical 1 - Total 30 hours)
Number of lectures: Three hours per week for 15 weeks

Prerequisite: Students who have completed a Three-Year Bachelor Degree in Science with Physics Major (Level 5.5)

Course Objectives:
1. To understand mathematical concepts used for solving physics problems.
2. To understand the basic principles of Physics from a mathematical point of view.

Course Outcomes (COs):
On completing the course, the student will be able to:

1. Develop skills to solve simple as well as complex physics problems by analytical methods.
2. Develop the ability to use Taylor's theorem and associated mathematical theorems in physical scenarios.
3. Develop the ability to solve second order partial differential equations to solve the essential problems in physics involving wave dynamics as well as quantum mechanics.
4. Understand the concepts of tensors, differential equations with varying coefficients, integral transforms and series and complex variables.
5. Use online resources for selecting innovative applied or interdisciplinary problems.
6. Compare the results obtained by both analytical and computational methods.

Unit 1 (15 lectures)

Series and Applications

1. **Infinite Series:** Fundamental concepts – convergence test: Cauchy's ratio test, Gauss's test alternating series – algebra of series. **Mean Value theorems:** Taylor theorem and series – Binomial theorem – power series – asymptotic series – Stirling's formula.
2. **Power series solutions of Differential Equations:** General treatment of second order linear differential equations with varying coefficients, Power series solutions, Frobenius method, Bessel, Legendre, Hermite and Laguerre polynomials.

Unit 2 (15 lectures)

Tensors and Integral Transforms

1. **Tensors:** Vector concepts - products, differentials and integrals, dual vector system, Index notation, Kronecker and Levi Civita tensors, inner and outer products, contraction, symmetric and antisymmetric tensors, quotient law, metric tensors, covariant and contravariant tensors.
2. **Integral transforms:** three dimensional fourier transforms and its applications to PDEs (Green function of Poisson's PDE), convolution theorem, Parseval's relation, Laplace transforms, Laplace transform of derivatives, Inverse Laplace transform and Convolution theorem, use of Laplace's transform in solving differential equations.

Unit 3 (15 lectures)

Complex Analysis

1. **Complex Variables:** Limits, Continuity, Derivatives, Cauchy-Riemann Equations, Analytic functions, Harmonic functions, Elementary functions: Exponential and Trigonometric, Conformal mapping (Self Study).
2. **Complex Integrals:** Taylor and Laurent series, Residues, Residue theorem, Principal part of the functions, Residues at poles, zeroes and poles of order m, Contour Integrals.

List Of Recommended Reference Books

1. G. Arfken and H. J. Weber: Mathematical Methods for Physicists, Academic Press, 2005.
2. E. Kreyszig Advanced Engineering Mathematics, 8th ed. John Wiley and Sons, 1999.
3. D. Fleisch: Student's Guide to Vectors and Tensors, Cambridge University Press, 2012

Additional references:

1. A.K. Ghatak, I.C. Goyal and S.J. Chua, Mathematical Physics, McMillan
2. A.C. Bajpai, L.R. Mustoe and D. Walker, Advanced Engineering Mathematics, John Wiley
3. E. Butkov, Mathematical Methods, Addison-Wesley
4. J. Mathews and R.L. Walker, Mathematical Methods of physics
5. P. Dennery and A. Krzywicki, Mathematics for physicists
6. T. Das and S.K. Sharma, Mathematical methods in Classical and Quantum Mechanics
7. R. V. Churchill and J.W. Brown, Complex variables and applications, V Ed. Mc Graw. Hill
8. A. W. Joshi, Matrices and Tensors in Physics, Wiley India
9. Mathematical Physics by B. D. Gupta

Practicals

1. Minimum four practicals in the complete semester from the following list:
   a. Numerical solution of simple problems.
   b. Gaussian elimination method of solution of linear system of equations.
   c. Numerical solution first order differential equations and coupled differential equations.
   d. Simulation of simple pendulum.
2. Project:

   In a complete semester, a student must perform one project related to the course.

MSc-I (Physics) Course Code: PSPHY6002CR1

Classical Mechanics

Credits: 4 (Theory 3 - Total 45 hours, Practical 1 - Total 30 hours)
Number of lectures: Three hours per week for 15 weeks

Prerequisite: Students who have completed a Three-Year Bachelor Degree in Science with Physics Major (Level 5.5)

Course Objectives:
1. To understand mechanics through Lagrangian and Hamiltonian formalism.
2. To understand the basic principles of Chaos

Course Outcomes (COs):
On completing the course, the student will be able to:
1. Understand the Lagrangian and Hamiltonian formulation for motion of mechanical systems.
2. Understand the Hamilton-Jacobi and action-angle approach to understanding motion in classical mechanics
3. Apply the Lagrangian and Hamiltonian approach to study familiar problems in mechanics like the problem of oscillations.
4. Use analytical and computational skills to solve problems relevant to mechanical systems.
5. Compare and evaluate the Lagrangian and Hamiltonian approaches in solving similar types of problems.
6. Creatively develop an understanding of chaotic systems.

<u>Unit 1</u> (15 lectures)
Lagrangian formalism
1. **Lagrange's Equations:** Lagrange's equations, velocity dependent potentials and the dissipation function, simple application of Lagrangian formulations, Hamilton's principle, some techniques of the calculus of variations, derivation of Lagrange's equations from Hamilton's principle, conservation theorems and symmetry properties
2. **Oscillations:** Formulation of the problem, The eigenvalue equation, frequency of free vibration and normal coordinates, free vibrations of a linear triatomic molecule, forced vibrations and the effect of dissipative forces

<u>Unit 2</u> (15 lectures)
Hamiltonian formalism
1. **The Hamilton Equations of Motion:** Legendre transformations and the Hamilton equations of motion, cyclic coordinates and conservation theorems, Routh's procedure, derivation of Hamilton's equations from a variational principle, the principle of least action
2. **Canonical Transformations:** The equations of canonical transformation, examples of canonical transformation, the harmonic oscillator, generating functions, the symplectic approach to canonical transformation, Poisson brackets and other canonical invariants,

infinitesimal canonical transformation and conservation theorems in the Poisson bracket formulation, the angular momentum Poisson bracket formulation

Unit 3 (15 lectures)

Advanced formalisms and Chaos theory

1. **Hamilton-Jacobi Theory and Action-Angle Variables:** The Hamilton-Jacobi equation for Hamilton's principle and characteristic functions, the harmonic oscillator problem as an example of the Hamilton-Jacobi method, separation of variables in the Hamilton-Jacobi equation, ignorable coordinates, action-angle variables in systems of one degree of freedom, action-angle variables for completely separable systems
2. **Classical Chaos:** Periodic motion, perturbations and the Kolmogorov-Arnold-Moser theorem, attractors, chaotic trajectories and Lyapunov exponents, Poincare maps, Henon-Heiles Hamiltonian, fractals and dimensionality.

List Of Recommended Reference Books

1. Classical Mechanics by H. Goldstein 3rd edition, Narosa Publishing Home, New Delhi.
2. Classical Mechanics by N.C. Rana and P.S. Joag, Tata McGraw-Hill Publishing Company Ltd. New Delhi.
3. Classical Mechanics by Gupta Kumar Sharma, Pragati Prakashan.
4. Classical Mechanics by Mondal, Prentice-Hall of India, Pvt. Ltd., New Delhi.
5. Classical Mechanics by J. C. Upadhyaya, Himalaya Publishing House.

Practicals

1. Minimum four practicals in the complete semester from the following list:
   a. Coupled torsional pendulum
   b. Symmetric spinning top
   c. Double pendulum simulation
   d. Kater’s pendulum
   e. The brachistochrone problem
3. Project:
   In a complete semester, a student must perform one project related to the course.

MSc-I (Physics) Course Code: PSPHY6003CR1

Quantum Mechanics

Credits: 4 (Theory 3 - Total 45 hours, Practical 1 - Total 30 hours)
Number of lectures: Three hours per week for 15 weeks

Prerequisite: Students who have completed a Three-Year Bachelor Degree in Science with Physics Major (Level 5.5)

Course Objectives:
1. To understand general formalism and Dirac notation in quantum mechanics.
2. Applications in three dimensional problems including angular momentum.
3. To understand the concept and principles of perturbative methods.

Course Outcomes (COs):
On completing the course, the student will be able to:
1. Understand general formalism and Dirac notation in quantum mechanics.
2. Master the applications of quantum mechanics in one-dimensional and three-dimensional physics problems.
3. Understand the details and significance of angular momentum in quantum mechanics.
4. Know the details of perturbation theory, approximation and variation methods.
5. Use online resources for selecting innovative applied or interdisciplinary problems related to any of the methods specified.
6. Use computational or analytical methods to solve the selected problems.

Unit 1 (15 lectures)

Fundamental formalism
1. **Formalism:** Linear Vector Spaces and operators, Dirac notation, Hilbert space, Hermitian operators and their properties, Matrix mechanics: Basis and representations, unitary transformations, the energy representation. Schrodinger, Heisenberg and interaction picture. Wave packet: Gaussian wave packet, Fourier transform. Schrodinger equation solutions: one dimensional problems: General properties of one dimensional Schrodinger equation.
2. **Schrodinger equation solutions: Three dimensional problems:** Harmonic oscillator by raising and lowering operators. Orbital angular momentum operators in cartesian and spherical polar coordinates, commutation and uncertainty relations, spherical harmonics, two particle problem – coordinates relative to centre of mass, radial equation for a spherically symmetric central potential.

Unit 2 (15 lectures)

Angular Momentum
1. **Angular Momentum operators:** Ladder operators, eigenvalues and eigenfunctions of L^2 and L_z using spherical harmonics, angular momentum and rotations.
2. **Total Angular Momentum and application:** Total angular momentum J; eigenvalues of

J^2 and J_z. Addition of angular momentum, coupled and uncoupled representation of eigenfunctions, Clebsch Gordon coefficient for $j_1 = j_2 = 1/2$ and $j_1 = 1$ and $j_2 = 1/2$. Angular momentum matrices, Pauli spin matrices, spin eigenfunctions, free particle wave function including spin, addition of two spins.

Unit 3 (15 lectures)

Perturbation Theory

1. **Time Independent Perturbation Theory:** First order and second order corrections to the energy eigenvalues and eigenfunctions. Degenerate perturbation Theory: first order correction to energy.
2. **Time dependent perturbation theory:** Harmonic perturbation, Fermi's Golden Rule, sudden and adiabatic approximations, applications.
3. **Approximation Methods:** Variation Method: Basic principle, applications to simple potential problems, He- atom. WKB Approximation: WKB approximation, turning points, connection formulas, Quantization conditions, applications.

List Of Recommended Reference Books

1. D J Griffiths, Introduction to Quantum Mechanics 4th Edition
2. A Ghatak and S Lokanathan, Quantum Mechanics: Theory and Applications, 5th edition.
3. Richard Liboff, Introductory Quantum Mechanics, 4th edition, Pearson.
4. N Zettili, Quantum Mechanics: Concepts and Applications, 2nd edition, Wiley.
5. J. Bjorken and S. Drell, Relativistic Quantum Mechanics, McGraw-Hill (1965).

Additional references:

1. W Greiner, Quantum Mechanics: An introduction, Springer, 2004
2. R Shankar, Principles of Quantum Mechanics, Springer, 1994

Practicals

1. Minimum four practicals in the complete semester from the following list:
   a. Simulation of a particle in an infinite/finite potential
   b. Simulation of a particle in a multidimensional potential box
   c. Simulation of particle in a delta function potential
   d. Experimental determination of Rydberg’s constant
   e. Hydrogen atom wave functions
2. Project:
   In a complete semester, a student must perform one project related to the course.

MSc-I (Physics) Course Code: PSPHY6004CR1

Nuclear Physics

Credits: 2 (Theory 2 - Total 30 hours)
Number of lectures: Two hours per week for 15 weeks

Prerequisite: Students who have completed a Three-Year Bachelor Degree in Science with Physics Major (Level 5.5)

Course Objectives:
1. To understand the fundamentals of nuclear and particle physics.
2. To study the physics of nuclear detectors and accelerators.

Course Outcomes (COs):
On completing the course, the student will be able to:
1. Apply their understanding to problems involving a deuteron.
2. Understand nuclear models and reactions.
3. Understand how nuclear reactors and detectors are built for energy production and detection.
4. Master the design of particle accelerators to produce elementary particles.
5. Apply their knowledge of elementary particles and the standard model.
6. Articulate the basics of quantum chromodynamics.

Unit 1 (10 lectures)

Physics at the nuclear level
1. **Deuteron Problem and its ground state properties**, Estimate the depth and size of (assume) square well potential, Tensor force as an example of non-central force, nucleon-nucleon scattering-qualitative discussion on results, Spin-orbit strong interaction between nucleon, double scattering experiment.
2. **Nuclear Models:** Shell Model (extreme single particle): Introduction, Assumptions, Evidences, Spin-orbit interactions, Predictions including Schmidt lines, limitations, collective model.

Unit 2 (10 lectures)

Nuclear reactions and instrumentation
1. **Nuclear Reactions:** Kinematics, scattering and reaction cross sections, Compound nuclear reaction, direct nuclear reaction.
2. **Nuclear Detectors:** Gamma ray spectrometer using NaI scintillation detector, High Purity Germanium detector, Multi-wire Proportional counter.
3. **Accelerators:** Cockroft Walten Generator, Van de Graaf Generator, Sloan and Lawrence type Linear Accelerator, Proton Linear Accelerator, Cyclotron and Synchrotron.

Unit 3 (10 lectures)

Particle Physics

1. **Introduction to the Standard Model:** The Eightfold way, the Quark Model, the November revolution and aftermath, The standard Model, Revision of the four forces, cross sections, decays and resonances
2. **Significant implications of particle physics:** Introduction to Quantum Chromodynamics. Weak interactions and Unification Schemes (qualitative description), Properties of Neutrino, helicity of Neutrino, Parity, Qualitative discussion on Parity violation in beta decay and Wu's Experiment, Charge conjugation, Time reversal, Qualitative introduction to CP violation and TCP theorem.

List Of Recommended Reference Books

1. Introductory Nuclear Physics, Kenneth Krane, Wiley India Pvt. Ltd.
2. Introduction to Elementary Particles, David Griffith, John Wiley and sons.
3. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo, Springer-Verlag
4. Radiation Detection and Measurement, Glenn F. Knoll, John Wiley and sons,Inc.
5. Particle Accelerators, Livingston, M. S.; Blewett, J.

Evaluation (Theory): Total marks per 2-credit course – 50

I. Formative Assessment 'for' Learning (continuous internal assessment - CIA to improve learning).
CIA - 20 marks
(Written test/ Field trip/ Sit-in exams/ Research article review/ Assignments/ Presentations/ MCQs)

II. Summative Assessment 'of' Learning (focus on outcomes, quantitative data for outcomes of instruction).
End Semester Examination – 30 marks

Evaluation (Theory): Total marks per 3-credit course – 100

I. Formative Assessment 'for' Learning (continuous internal assessment - CIA to improve learning).
CIA - 40 marks
CIA 1: Written test - 20 marks
CIA 2: Field trip/ Sit-in exams/ Research article review/ Assignments/ Presentations/ MCQs - 20 marks

II. Summative Assessment 'of' Learning (focus on outcomes, quantitative data for outcomes of instruction).

End Semester Examination – 60 marks

Evaluation (Practical): Total marks per course - 50

Project work with report – 20 marks
End Semester Practical Examination – 20 marks
Journal – 5 marks
Co-curricular activity – 5 marks

Template for the End Semester examination in Semester I for the Core course

UNITS	KNOWLEDGE	UNDERSTANDING	APPLICATION and ANALYSES	TOTAL MARKS- Per unit
1	3 or 6	4 or 8	3 or 6	10 or 20
2	3 or 6	4 or 8	3 or 6	10 or 20
3	3 or 6	4 or 8	3 or 6	10 or 20
-TOTAL- Per objective	9 or 18	12 or 24	9 or 18	30 or 60
% WEIGHTAGE	30%	40%	30%	100%

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Syllabus

Second Semester Courses in MSc (Physics)

2023-2024

Contents:

MSc-I (Physics) Course Code: PSPHY6005CR1

Statistical Mechanics

Credits: 4 (Theory 3 - Total 45 hours, Practical 1 - Total 30 hours)
Number of lectures: Three hours per week for 15 weeks

Prerequisite: Students who have completed a Three-Year Bachelor Degree in Science with Physics Major (Level 5.5)

Course Objectives:
1. To develop an understanding of the principles of classical and quantum statistics and its applications to realistic problems.

Course Outcomes (COs):
On completing the course, the student will be able to:
1. Understand the concepts of phase space and the ensemble theories.
2. Apply the statistical basis of classical and quantum thermodynamics, to gain understanding of different physical systems.
3. Analyse, evaluate and make inferences using specific types of theories in specific problem sets and experimental situations.
4. Understand phase transitions and simple models of phase transitions.
5. Creatively apply classical and quantum statistics to various physical systems such as ultracold gases, stars etc.
6. Understand and apply the basic principles of non-equilibrium statistical mechanics.

<u>Unit 1</u> (15 lectures)
Classical Statistics
1. **The Fundamentals of statistical mechanics:** Macroscopic and microscopic states, physical significance of number of microstates, statistics & thermodynamics, entropy and Gibbs paradox, Phase space, Liouville's theorem, microcanonical ensemble
2. **The Canonical Ensemble:** Equilibrium between a system and heat reservoir, various statistical quantities in the canonical ensemble, partition function, energy fluctuations, system of harmonic oscillators, statistics of paramagnetism
3. **The Grand Canonical Ensemble:** Equilibrium between a system and a particle-energy reservoir, system in a grand canonical ensemble, density and energy fluctuations in the grand canonical ensemble

<u>Unit 2</u> (15 lectures)
Quantum Statistics
1. **Quantum Statistics:** Systems composed of indistinguishable particles, density matrix and the partition function, quantum-mechanical analogue of the Liouville equation, statistics of occupation numbers, kinetic considerations in a simple gas, gaseous systems composed of molecules with internal motion

2. **Bose and Fermi systems:** Bose-Einstein condensation in ultracold atomic gases, superfluidity, the electron gas in metals, statistical equilibrium of white dwarf stars
3. **Thermodynamics of the Early Universe:** Big Bang, and evolution of the temperature of the Universe, relativistic electrons, positrons and the neutrinos, neutron fraction, annihilation of the positrons and electrons, neutrino temperature, primordial nucleosynthesis, recombination

Unit 3 (15 lectures)

Phase transitions, non-equilibrium statistical mechanics and applications

1. **Phases and phase transitions:** Thermodynamic phase diagrams, chemical equilibrium, phase equilibrium and the Clausius-Clapeyron equation, condensation of van der Waals gas, Ising model in the zeroth approximation, Introduction to Ising model in the first approximation, Critical exponents
2. **Fluctuations and nonequilibrium statistical mechanics:** Equilibrium thermodynamic fluctuations, the Einstein-Smoluchowski theory of the Brownian motion, approach to equilibrium: the Fokker- Planck equation and Langevin theory of Brownian motion
3. **Applications of statistical mechanics:** Information theory, economics, biological systems (brief overview)

List Of Recommended Reference Books

1. Statistical Mechanics, R. K. Pathria & Paul D. Beale, 3rd edition, Elsevier publication 2011
2. Statistical Mechanics, Kerson Huang, 2nd edition, John Wiley & Sons publication 1987
3. Fundamentals of Statistical and Thermal Physics, F. Reif, 1st edition, Levant books publication 2010
4. Introductory Statistical Mechanics, Roger Bowley and Mariana Sanchez, South Asia edition, Oxford Science Publications 2013
5. Introduction to Statistical Mechanics , S. K. Sinha, 3rd edition, Narosa Publication 2011
6. Elements of Nonequilibrium Statistical Mechanics, V. Balakrishnan, Ane's student edition, Ane Books Pvt Ltd 2014

Additional references:

1. Statistical Physics of Particles, Mehran Kardar
2. Statistical Physics for Biological Matter, Wokyung Sung, Springer

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Practicals

1. Minimum four practicals in the complete semester from the following list:
    a. Study of microstates in an Einstein solid
    b. Simple molecular dynamics simulation
    c. Comparative study of diffusion and random walk
    d. Experimental determination of Fermi temperature/energy
2. Project:
   In a complete semester a student must perform one project related to the course.

MSc-I (Physics) Course Code: PSPHY6006CR1

Electrodynamics

Credits: 4 (Theory 3 - Total 45 hours, Practical 1 - Total 30 hours)
Number of lectures: Three hours per week for 15 weeks

Prerequisite: Students who have completed a Three-Year Bachelor Degree in Science with Physics Major (Level 5.5)

Course Objectives:
1. To understand dispersion and propagation of Electromagnetic waves.
2. To analyse radiating systems and multipole fields.
3. To understand the advanced concepts of special theory of relativity.

Course Outcomes (COs):
On completing the course, the student will be able to:
1. Understand the fundamental concepts and properties of electromagnetic waves.
2. Understand and analyse dispersive properties of and propagation of electromagnetic waves in materials - conductors, dielectrics and plasmas.
3. Analyse the behaviour of electromagnetic fields in waveguides.
4. Understand radiating systems and analyse multipole radiation in atoms and nuclei.
5. Creatively apply the physics of special relativity in various applications.
6. Understand and apply the tensorial notation in the context of special relativity.

Unit 1 (15 lectures)

Plane Electromagnetic Waves And Wave Propagation
1. **Electromagnetic Wave in different media: Review:** (Discussion in the class after student reading). Plane Waves in a Non conducting Medium, Linear and Circular Polarisation; Stokes Parameters, Reflection and Refraction of Electromagnetic Waves at a Plane Interface Between Two Dielectrics, Polarisation by Reflection, Total Internal Reflection.
2. **Wave packet in different media:** Goos–Hänchen Effect, Frequency Dispersion Characteristics of Dielectrics, Conductors, Superposition of Waves in One Dimension; Group Velocity, Illustration of the Spreading of a Pulse As It Propagates in a Dispersive Medium, Causality in the Connection Between D and E; Kramers–Kronig Relations, Arrival of a Signal After Propagation Through a Dispersive Medium.
3. **Waveguides, Resonant Cavities and Optical Fibres:** Fields at the Surface of and Within a Conductor, Cylindrical Cavities and Waveguides, Waveguides, Modes in a Rectangular Waveguide, Energy Flow and Attenuation in Waveguides, Resonant Cavities, Power Losses in a Cavity; *Q* of a Cavity, Modes in Dielectric Waveguides, Multimode Propagation in Optical Fibres.

Unit 2 (15 lectures)

Electromagnetic Fields

1. **Radiating Systems, Multipole Fields and Radiation:** Fields and Radiation of a Localised Oscillating Source, Electric Dipole Fields and Radiation, Magnetic Dipole and Electric Quadrupole Fields, Center-Fed Linear Antenna, Spherical Wave Solutions of the Scalar Wave Equation, Multipole Expansion of the Electromagnetic Fields, Multipole Radiation from a Linear, Centre-Fed Antenna.
2. **Radiation From Moving Charges:** Retarded Potentials of Single Moving Charges - The Lienard-Wiechert Potentials, The Velocity and Radiation Fields, Radiation from Non-relativistic Systems of Particles, Radiation from Harmonically Bound Particles

Unit 3 (15 lectures)

Relativity

1. **Relativistic Covariance And Kinematics:** Review: Special theory of relativity, Lorentz Transformations, Four-Vectors: applications in spacetime, energy-momentum, angular frequency-wave vector, scalar potential-vector potential, Tensor Analysis, Matrix Representation of Lorentz Transformations, Covariance of Electromagnetic Phenomena, Fields of a Uniformly Moving Charge, Emission from Relativistic Particles, Invariant Phase Volumes and Specific Intensity, Electromagnetic field tensor.
2. **Relativity using tensors:** Tensor analysis in special relativity: The metric tensor, Definition of tensors, The (0,1) tensors: one-forms, The (0,2) Tensor, Metric as a mapping of vectors into one-forms, (M, N) tensors, Index ‘raising’ and ‘lowering’, Tensor notation of general 3-dimensional Lorentz Transformation of velocities. Differentiation of tensors; Perfect fluids in special relativity: Fluids, Dust, General fluids, Perfect fluids, Importance for general relativity, Gauss’ law.

List Of Recommended Reference Books

1. Classical Electrodynamics, J. D. Jackson, 3 rd edition, John Wiley and Sons pvt. Ltd.
2. Classical Electromagnetic Radiation, 3 rd edition, M. A. Heald and J. B. Marion, Saunders college Publishing.
3. Electromagnetic Waves and Radiating Systems, 2 nd edition, E. C. Jordan and K. G. Balmain, Prentice Hall Inc.
4. Radiative Processes In Astrophysics by George B. Rybicki and Alan P. Lightman, WILEY VCH Verlag GmbH & Co. KGaA, Weinheim.
5. A First Course in General Relativity, Second Edition, by Bernard F. Schutz, Cambridge University Press.
6. Introducing Einstein’s relativity by Ray d’Inverno.

Additional references:

1. Gravitation, C W Misner, K S Thorne, and J A Wheeler, W H Freeman & Co.

Practicals

1. Minimum four practicals in the complete semester from the following list:
   a. Simulation of wave polarisation.
   b. Phonon dispersion relation.
   c. Simulation of electromagnetic fields.
   d. Simulation of special relativity.
2. Project:
   In a complete semester a student must perform one project related to the course.

MSc-I (Physics) Course Code: PSPHY6007CR1

Atomic and Molecular Physics

Credits: 4 (Theory 3 - Total 45 hours, Practical 1 - Total 30 hours)
Number of lectures: Three hours per week for 15 weeks

Prerequisite: Students who have completed a Three-Year Bachelor Degree in Science with Physics Major (Level 5.5)

Course Objectives:
1. To apply the formalism of quantum mechanics to study atomic systems and their interaction with electromagnetic fields.
2. To understand the basic building blocks of matter in terms of multi-electron atoms and molecules and their basic fundamental properties.

Course Outcomes (COs):
On completing the course, the student will be able to:
1. Understand and analyse the simple atomic structure described by quantum physics, and interaction of atoms with electromagnetic fields.
2. Apply a simple atomic model to analyse problems in physical and biological sciences.
3. Understand complex atomic models and their consequences.
4. Use various spectroscopy techniques to understand the theory of the atomic models.
5. Use online resources to analyse the data obtained from various databases to understand atomic and molecular spectroscopy.
6. Create programs or data analyses and interpretation projects to further the knowledge of atomic and molecular processes in astrophysical or laboratory experimental contexts.

<u>Unit 1</u> (15 lectures)
One and Two Electron Atoms
1. **Review:** Solution to Hydrogen atom problem: Spherical Harmonics and the radial solution. Interaction of one-electron atoms with electromagnetic radiation.
2. **One-electron atom:** Fine structure of hydrogenic atoms, The Zeeman effect, The Stark effect, The Lamb shift, Hyperfine structure and isotope shifts, Problems.
3. **Two-electron atoms**: The Schrodinger equation for two-electron atoms, Para and ortho states, Spin wave functions and the role of the Pauli exclusion principle, The independent particle model, The ground state of two-electron atoms, Excited states of two-electron atoms, Doubly excited states of two-electron atoms. Auger effect (autoionization), Resonances, Problems.

<u>Unit 2</u> (15 lectures)
Many-electron atoms
1. **Many-electron atoms:** The central field approximation, The periodic system of the element, The Thomas-Fermi model of the atom, The Hartree-Fock method and the self-

consistent field, Corrections to the central field approximation, L-S coupling and j-j coupling, Problems.

2. **The interaction of many-electron atoms with electromagnetic fields:** Selection rules, The spectra of the alkalis, Helium and the alkaline earths, Atoms with several optically active electrons. Multiplet structure Interaction with magnetic fields. Zeeman Effect, The quadratic Stark effect, X-ray spectra
3. **Some applications of atomic physics:** Magnetic resonance and the measurement of gyromagnetic Masers and lasers, Controlled thermonuclear fusion, Astrophysics Problems**.**

Unit 3 (15 lectures)

Molecular Physics

1. **Molecular spectroscopy:** Pure Rotation Spectra - diatomic and polyatomic molecules, Rotation-Vibration Spectra, the interaction of rotation and vibration, vibration of polyatomic molecules, Electronic-Rotational-Vibrational Spectra Energy Levels
2. **Molecular Structure:** The Born-Oppenheimer Approximation, Nuclear Motion in Diatomic Molecules, Electronic Binding of Nuclei: The H_2^+ Ion - excited states molecular orbitals, The H_2 Molecule - homonuclear diatomic molecular orbits

List Of Recommended Reference Books

1. Robert Eisberg and Robert Resnick, Quantum physics of Atoms, Molecules, Solids, Nuclei and Particles, John Wiley & Sons, 2nd ed, (ER).
2. B. H. Bransden and G. J. Joachain, Physics of atoms and molecules, Pearson Education 2nd ed, 2004 (BJ).
3. G. K. Woodgate, Elementary Atomic Structure, Oxford university press, 2nd ed, (GW).
4. Quantum Chemistry by Ira Levine, Pearson publications, chapter 13
5. Fundamentals of Molecular Spectroscopy 4th Ed, C N Banwell and E M McCash, McGraw Hill
6. Radiative Processes In Astrophysics by George B. Rybicki and Alan P. Lightman, WILEY VCH Verlag GmbH & Co. KGaA, Weinheim

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Practicals

1. Minimum four Experiments in the complete semester from the following list:
    a. Numerical exploration of external fields on H-atom.
    b. Exploration of application of Hartree-Fock method for multi-electron atoms.
    c. Simulation of SHM as a precursor to vibration in molecules.
    d. Simulation of molecules.
2. Project
   In a complete semester a student must perform one project related to the course.

MSc-I (Physics) Course Code: PSPHY6008CR1

Solid State Physics

Credits: 2 (Theory 2 - Total 30 hours)
Number of lectures: Two hours per week for 15 weeks

Prerequisite: Students who have completed a Three-Year Bachelor Degree in Science with Physics Major (Level 5.5)

Course Objectives:
1. To study the characteristics of phonons, optical and magnetic properties of solids.

Course Outcomes (COs):
On completing the course, the student will be able to:
1. Understand lattice vibrations.
2. Apply knowledge of thermal properties of a material such as conductivity.
3. Understand optical properties of materials.
4. Compare magnetic properties of different types of materials.
5. Identify domain structure in different types of materials
6. Apply knowledge of solid state physics in the society, for example, to synthesise and characterise novel materials which can be used in devices.

Unit 1 (10 lectures)
Lattice Vibrations And Thermal Properties
1. **Vibrations of Monoatomic Lattice**, normal mode frequencies, dispersion relation. Lattice with two atoms per unit cell, normal mode frequencies, dispersion relation.
2. **Quantization of lattice vibrations**, phonon momentum, Inelastic scattering of neutrons by phonons, Surface vibrations, Inelastic Neutron scattering. Anharmonic Crystal Interaction.
3. **Thermal conductivity** – Lattice Thermal Resistivity, Umklapp Process, Imperfections

Unit 2 (10 lectures)
Optical Properties Of Solids
1. **Optical Properties**: Scattering, transmission and absorption in solid. optical properties of semiconductors, optical transitions, excitons, activators
2. **Franck-Condon principle**, colour centres, photoluminescence and thermoluminescence.

Unit 3 (10 lectures)
Magnetic Properties
1. **Magnetic properties**: dia, para and ferromagnetic materials, Origin of magnetism – various theories, temperature dependence.
2. **Domain structure**, ferromagnetic domains, antiferromagnetism, magnetic hysteresis and coercive force.

List Of Recommended Reference Books

1. Solid state Physics – N.N. Ashcroft and N.D. Mermin
2. Charles Kittel "Introduction to Solid State Physics", 7th edition John Wiley & sons.
3. M.A.Wahab "Solid State Physics –Structure and properties of Materials" Narosa Publications 1999.
4. M. Ali Omar "Elementary Solid State Physics" Addison Wesley (LPE).

Evaluation (Theory): Total marks per 2-credit course – 50

I. Formative Assessment 'for' Learning (continuous internal assessment - CIA to improve learning).
CIA - 20 marks
(Written test/ Field trip/ Sit-in exams/ Research article review/ Assignments/ Presentations/ MCQs)

II. Summative Assessment 'of' Learning (focus on outcomes, quantitative data for outcomes of instruction).
End Semester Examination – 30 marks

Evaluation (Theory): Total marks per 3-credit course – 100

I. Formative Assessment 'for' Learning (continuous internal assessment - CIA to improve learning).
CIA - 40 marks
CIA 1: Written test - 20 marks
CIA 2: Field trip/ Sit-in exams/ Research article review/ Assignments/ Presentations/ MCQs - 20 marks

II. Summative Assessment 'of' Learning (focus on outcomes, quantitative data for outcomes of instruction).

End Semester Examination – 60 marks

Evaluation (Practical): Total marks per course - 50

Project work with report – 20 marks
End Semester Practical Examination – 20 marks
Journal – 5 marks
Co-curricular activity – 5 marks

Template for the End Semester examination in Semester II for the Core course

UNITS	KNOWLEDGE	UNDERSTANDING	APPLICATION and ANALYSES	TOTAL MARKS- Per unit
1	3 or 6	4 or 8	3 or 6	10 or 20
2	3 or 6	4 or 8	3 or 6	10 or 20
3	3 or 6	4 or 8	3 or 6	10 or 20
-TOTAL- Per objective	9 or 18	12 or 24	9 or 18	30 or 60
% WEIGHTAGE	30%	40%	30%	100%

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