BODOLAND UNIVERSITY

Syllabus for
2 Year PG Programme
in
PHYSICS

Framed According to National Education Policy (NEP 2020)
Effective from Academic Year 2024-25

Abbreviations used for Paper Code

Abbreviations used:

MAJ: Major

MIN: Minor

IDC: Inter Disciplinary Course

AEC: Ability Enhancement Courses

SEC: Skill Enhancement Course

VAC: Value Added Course

DIS: Dissertation

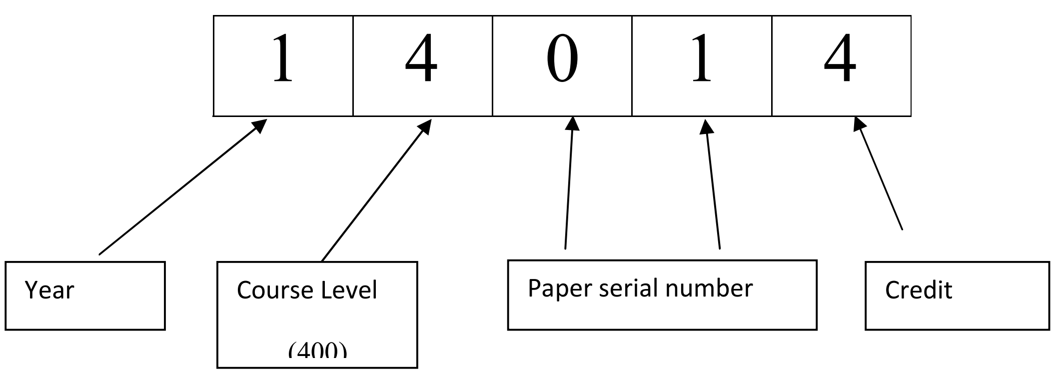
REM: Research Methodology

ADL: Advance Learning

SPL: Specialized Learning

RES: Research

Digit Explanation example:



Curriculum Structures
for
2 Year PG Programme

Total Credits = 80

SEMESTER - I							
Paper Code	**Paper title**	**Credit**	**Credit Distribution (L+T+P)**	**End Semester Marks**	**Internal Marks**	**Practical**	**Total Marks**
PHYADL14014	Atomic and Molecular Physics	4	(3+1+0)	70	30	00	100
PHYADL14024	Electronics	4	(3+1+0)	70	30	00	100
PHYADL14034	Quantum Mechanics - II	4	(3+1+0)	70	30	00	100
PHYADL14044	Research Methodology	4	(3+1+0)	70	30	00	100
PHYADL14054	**Physics Practical - I**	4	(0+0+4)	00	30	70	100
Total Credits		**20**					**500**

SEMESTER - II							
Paper Code	**Paper title**	**Credit**	**Credit Distribution (L+T+P)**	**End Semester Marks**	**Internal Marks**	**Practical**	**Total Marks**
PHYADL14064	Advanced Statistical Mechanics	4	(3+1+0)	70	30	00	100
PHYSPL15074	Nuclear and Particle Physics - II	4	(3+1+0)	70	30	00	100
PHYSPL15084	Condensed Matter Physics - I	4	(3+1+0)	70	30	00	100
PHYSPL15094	Advanced Optics - I	4	(3+1+0)	70	30	00	100
PHYSPL15104	Physics Practical - II	4	(0+0+4)	00	30	70	100
Total Credits		**20**					**500**

Options

Option 1: Course Work & Research	Course work: Sem. III; Research: Sem. IV
Option 2: Course work only	Course work: Sem. III & IV
Option 3: Only Research	Research: Sem. III & IV

Option 1: Course Work & Research

SEMESTER – III					
Course Code	**Subject**	**Credit (L+T+P)**	**End Sem. Marks**	**Internal Marks**	**Total Marks**
PHYSPL25014	Advanced Nuclear and Particle Physics	4 (3+1+0)	70	30	100
PHYSPL25024	Condensed Matter Physics	4 (3+1+0)	70	30	100
PHYSPL25034	Experimental Techniques in Physics	4 (3+1+0)	70	30	100
PHYSPL25044	Computational Physics	4 (3+1+0)	70	30	100
PHYSPL25054	Physics Practical-III	4 (0+0+4)	70	30	100
Total Credits		**20**			**500**

SEMESTER – IV			
Course Code	**Subject**	**Credit**	**Total marks**
PHYRES250120	Research	20	500
Total Credits		**20**	**500**

Option 2: Course Work only

SEMESTER – III					
Course Code	**Subject**	**Credit (L+T+P)**	**End Sem. Marks**	**Internal Marks**	**Total Marks**
PHYSPL25014	Advanced Nuclear and Particle Physics	4 (3+1+0)	70	30	100
PHYSPL25024	Condensed Matter Physics	4 (3+1+0)	70	30	100
PHYSPL25034	Experimental Techniques in Physics	4 (3+1+0)	70	30	100
PHYSPL25044	Computational Physics	4 (3+1+0)	70	30	100
PHYSPL25054	Physics Practical-III	4 (0+0+4)	70	30	100
Total Credits		**20**			**500**

SEMESTER – IV					
Code	Subject	Credit (L+T+P)	End Sem. Marks	Internal Marks	Total Marks
PHYSPL25064	Plasma Physics	4 (3+1+0)	70	30	100
PHYSPL25074	Advanced Optics - II	4 (3+1+0)	70	30	100
PHYSPL25084	Vacuum Science & Technology	4 (3+1+0)	70	30	100
PHYSPL25094	Nanoscience & Technology	4 (3+1+0)	70	30	100
PHYSPL25104	Literature survey on research topic	4 (0+0+4)	70	30	100
Total Credits		**20**			**500**

Option 3: Only Research

SEMESTER- III			
Code	Subject	Credit	Total marks
PHYRES250120	Research	20	500
Total Credits		**20**	**500**
SEMESTER-IV			
Code	Subject	Credit	Total marks
PHYRES250220	Research	20	500
Total Credits		**20**	**500**

Semester 1

Paper Title: Atomic and Molecular Physics

Paper Code: PHYADL14014

Credit: 04 (3+1+0)

Total lecture: 48

Course Objective: *The course has been designed to provide idea on atomic and molecular structure, various interaction phenomena inside atoms and molecules.*

Course Outcome: *The students are expected to*

Get the evidence of stability of atoms by studying various atomic models.

Use spectroscopic techniques to identify elements present in a sample

Learn about the effect of electric and magnetic fields on atoms

Learn about spectra generated due to molecular behavior

Unit I:

Problems with Rutherford model, Hydrogen and Alkai spectra: Series in hydrogen, Bohr's correspondence principle, Sommerfeld model, Vector atom model, space quantization, Stern Gerlach experiment and intrinsic spin of electron. Spectra of sodium atom. Doublet structure of D lines of sodium, Coupling schemes: L-S, j-j and intermediate coupling, alkali spectra, fine and hyperfine structure in alkali spectra, Magnetic moment of electron, Lande g factor, selection rules, Lande's interval rule, intensity rules, regularities in complex spectra, Pauli exclusion principle, shell structure, Hund's rule, spectral terms from two equivalent electrons. **(13 lectures)**

Unit II

Normal and anomalous Zeeman effect, Classical and Quantum theory of Zeeman effect, Zeeman patterns of sodium and mercury, Zeeman pattern of various transitions, Paschen Back effects, Stark effect in hydrogen, hyperfine structure and determination of nuclear spin and nuclear g factors, radiative transition probabilities, line width: Doppler broadening, natural broadening, collision broadening and Stark broadening, X-Ray: Continuous and Characteristic X-rays, Mosley's law and its explanation. **(12 lectures)**

Unit III

Rigid rotator- energy levels, spectrum, intensity of rotational lines, energy levels, eigenfunctions, transition probabilities and selection rules, spectrum, Nonrigid rotator- energy levels, spectrum, isotope effect on rotational spectra.

Born and Oppenheimer approximation, Vibration of diatomic molecules, harmonic oscillator, energy levels, anharmonicity, Rotation-vibration spectra of diatomic molecules, PQR branching, isotope effect in vibrational bands, Frank-Condon principle. (**12 lectures)**

Unit IV

Classical and Quantum theory of Raman Effect, Vibrational Raman spectra, Stokes and anti-Stokes lines, rotational Raman spectra, Infra red spectra vs Raman spectra, Applications of

Raman effect. NMR & ESR spectra: Magnetic properties of nuclei, nuclear resonance, Spin-spin & spin-lattice interaction, chemical shift, nuclear coupling. **(11 lectures)**

Reference Books:

1. Atomic Spectra: H.E. White (McGraw Hill) 1934.
2. Fundamentals of Molecular spectroscopy: Banwell and McCash (Tata McGraw Hill), 1994.
3. Physics of Atoms and Molecules, BH Bransden, CJ Joachain, Pearson, 2013
4. Atomic Spectra − JB Rajam , S Chand & Company Ltd.
5. Atomic & Molecular Spectra: Laser, Raj Kumar, Kedar Nath Ram Nath
6. Molecular Structure and Spectroscopy, G Aruldhas, PHI Learning Pvt Ltd, Delhi
7. Atomic, Molecular and Photons, Wolfgang Damtrodes (Springer), 2010.
8. Molecular Spectra and Molecular Structure I: G. Herzberg (Van-Nostrand Rein-hold), 1950.

Semester 1

Course Code: PHYADL14024

Course Title: Electronics

Total Credit: 4 (3+1+0)

Total Lecture: 48

Course Learning Outcomes: *After completion of the course, the students will be equipped with required knowledge in electronic devices, circuits and their applications. The students will be able to learn about digital circuits and microprocessors. The students will get to know the basic concept of signal transmission, and the role of modulation and demodulation in signal transmission.*

Unit - I: MOS and CMOS devices and applications

Static & dynamic characteristics, depletion & enhancement modes, use of the devices in amplifiers and oscillators. **(4 lectures)**

Unit - II: Tunnel Diode and Applications

Tunneling effect, transfer coefficient, tunnel diode characteristics, use of tunnel diode as oscillator and amplifier. **(2 lectures)**

Unit - III: Gunn Diode and Applications

Transferred electron effect, modes of TE oscillations, Gunn diode in oscillation circuit. **(2 lectures)**

Unit - IV: Impatt / Avalanche Diode and Applications

Drift and scattering velocity, relation between field, current and terminal impedance, equivalent circuit of the diodes and their use in amplifiers and oscillators. **(4 lectures)**

Unit - V: OP-AMP Applications

Oscillators: Phase shift, Wien bridge and high frequency and voltage controlled oscillators, sawtooth generator. Filters: Active low and high pass filters, Butterworth filter (up to second order). Analog computation: Solution of differential equation (up to second order), solution of simultaneous equations. **(8 lectures)**

Unit - VI: Digital Circuits

Mapping of logic expression and function minimization: SOP, POS expressions and circuit configurations, Combinational Logic gates, working and configuration of TTL, DTL, RTL, CMOS, MOSFET, Sequential circuits: RS, JK, D and TFF; Register: serial, parallel and shift register-their design, Counter: synchronous counter and design (up to module–10 counter), Microprocessor: basic concept. **(10 lectures)**

Unit - VII: Signal Transmission & Devices

Transmission line: Basic concept of transmission of LF and HF in open wire and coaxial lines, wave equation, characteristic impedance, VSWR, Short and open circuit impedance, λ-matching and stub matching, Waveguides: fundamental concepts of signal propagation through a waveguide, relation between cutoff frequency and waveguide dimension of rectangular waveguide, Antenna: monopole and dipole antenna, antenna parameter, antenna array. **(10 lectures)**

Unit - VIII: Modulation and Demodulation:

Amplitude modulation: Bandwidth and frequency spectra, Frequency modulation: narrowband and wide band, power, bandwidth, improvement of S/N with emphasis and de-emphasis circuits, Pulse Modulation: PAM, PCM Basic idea of digital carrier modulation schemes and Channel capacity. **(8 lectures)**

Recommended Books:

1. Modern Digital Electronics – R.P. Jain
2. Electronic Communication Systems – Kennedy, Davis
3. Microwaves – K.C. Gupta
4. Op-Amps and Linear Integrated Circuits – R.A. GayaKwad
5. Digital Principles and Applications – A.P. Malvino and D.J. Leach
6. Electronic Devices – Thomas L. Floyd
7. Fundamentals of Digital Electronics – A. Kumar

Semester 1

Course Code: PHYADL14034

Course Title: Quantum Mechanics-II

Total Credit: 4 (3+1+0)

Total Lecture: 48

Course objectives: *The objective of the paper is to provide exposer to the learners about some advanced concepts in both non-relativistic and relativistic quantum mechanics and their applications to solve the problems of the subatomic world.*

Course Learning Outcomes: *After learning this course, the learners will be able to (a) use Dirac's bra-ket algebra to derive generalized uncertainty principle and solve 1D harmonic oscillator problem (b) compare the different pictures in Quantum Mechanics (c) apply various approximation methods such as time-independent perturbation theory, variational principle and WKB approximation to solve quantum mechanical problems (d) write matrix representation of angular momentum and calculate eigenfunctions of orbital angular momentum (e) analyze orbital and spin angular momentum matrices and calculate Clebsch-Gordan coefficients, (f) illustrate continuous and discrete symmetries in QM and apply the identical particle QM to the collision of identical particles (g) use time-dependent perturbation theory for constant and harmonic perturbations and derive Fermi's Golden rule (h) derive KG and Dirac equation in presence of electromagnetic field.*

Unit - I: Operator method in Quantum Mechanics

Introduction to linear vector space, Hilbert space, observables and operators, Dirac notations – Properties of state vectors – Ket and Bra vectors, Orthogonal and Orthonormal states. Projection Operators, Commutator Algebra, Uncertainty principle for two arbitrary operators, One dimensional linear harmonic oscillator problem by operator method. **(8 lectures)**

Unit - II: Time evolution of states

Evolution of states, unitary time evolution operator, Schrodinger and Heisenberg pictures. Heisenberg's equation of motion, Dirac interaction picture. **(3 lectures)**

Unit - III: Symmetry and Identical Particles

Symmetry and conservation laws, Translation in space: conservation of linear momentum, Translation in time: Conservation of energy, Rotation in space: Conservation of angular momentum, Space Inversion: parity conservation, Time reversal. Meaning of identity and consequences; Symmetric and antisymmetric wave functions; Slater determinant; Symmetric and antisymmetric spin wave functions of two identical particles; Collisions of identical particles. **(7 lectures)**

Unit - IV: Angular Momentum

The orbital angular momentum operator, general formalism of angular momentum, matrix representation of angular momentum, eigenfunctions of orbital angular momentum, angular momentum in differential representation using spherical coordinates, spherical harmonics; Raising and lowering operators for angular momentum using Bra and Ket algebra. Spin angular momentum, experimental evidence for spin (Stern-Gerlach Experiment), spin-half and Pauli matrices. Addition of angular momenta and Clebsch-Gordon coefficients. **(8 lectures)**

Unit - V: Approximation Methods

Time independent perturbation theory: First and second order corrections to the energy eigenvalues; First order correction to the eigenvector; Degenerate perturbation theory; Applications to Zeeman Effect and isotopic shift. Variational methods and its applications. Wentzel - Kramers - Brillouin (WBK) Method and its application. **(9 lectures)**

Unit - VII: Scattering theory

Differential and total scattering cross-sections, scattering amplitude; Scattering by spherically symmetric potentials; Partial wave analysis and phase shifts; Scattering by a rigid sphere and square well; Coulomb scattering; Born approximation. **(7 lectures)**

Unit - VIII: Relativistic Quantum Mechanics

Single particle relativistic wave equation, Klein-Gordon equation, Dirac equation, prediction of antiparticles, non-relativistic limit and electron magnetic moment. **(6 lectures)**

Books recommended:

1. Introduction to Quantum Mechanics – David J Griffiths (2nd Ed. Pearson)
2. Principles of Quantum Mechanics – R. Shankar (3rd Ed. Springer)
3. Quantum mechanics – A. Ghatak and S. Lokanathan (Springer)
4. Quantum Mechanics – Concepts and Applications N. Zettili (2nd Ed. Wiley)
5. Quantum mechanics – G. Auletta, M. Fortunato, G. Parisi (Cambridge Univ. Press)
6. Quantum Mechanics: An Introduction – Walter Greiner (4th Ed. Springer)
7. Modern Quantum Mechanics – J .J. Sakurai (2nd Ed. Pearson)
8. The Principles of Quantum Mechanics –P. A. M. Dirac (B.N. Publishing)
9. The Feynman Lectures on Physics –R. Feynman, R. Leighton and M. Sands
10. Quantum Mechanics –C. Cohen-Tannoudji, B. Diu, and F. Lalo. (2nd Ed., Wiley-VCH)
11. Modern Particle Physics - Mark Thomson (Cambridge University Press)
12. Relativistic Quantum Mechanics – J.D. Bjorken and S.D. Drell
13. Introductory Quantum Mechanics – Richard L. Liboff.
14. Quantum Mechanics – C. Cohen-Tannoudji, B. Diu, and F. Lalo.
15. Modern Particle Physics - Mark Thomson (Cambridge University Press)

Semester 1

Course Code: PHYADL14044

Course Title: Research Methodology

Total Credit: 4 (3+1+0)

Total Lecture: 48

Course Objective: *The objective of the course is to familiarize the students with the concepts of research, research design, ethics of research and consequences of plagiarism and how to write technical reports and papers.*

Course Outcome: *After this course, the candidates will have basic concepts of research, research design, organize and conduct research more appropriate way and able to write research report, thesis, project proposals. The candidates will have proper idea about research ethics, plgarims and its tools. .*

Unit I: Research Methodology: An introduction

Research concept, identification of research problem, Meaning of Research, Objectives of Research Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Research Process, Criteria of Good Research. **(12 Lecture)**

Unit II: Research Design

Meaning of Research Design, Need for Research Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs. **(8 Lecture)**

Unit III: Scientific Writing

Forms of scientific writing i.e. research articles, notes, report, review, monograph, dissertation/thesis, popular article etc. components of research article, writing strategy for a research article. **(8 Lecture)**

Unit IV: Intellectual Property Right

Introduction to IPR, Patent laws, process of patenting a research finding, copyright. **(6 Lecture)**

Unit V: Philosophy and Ethics

Introduction to philosophy: definition, nature and scope, concept, branches, Ethics: definition, moral philosophy, nature of moral judgements and reactions. **(6 Lecture)**

Unit - VI: Scientific Conduct

Ethics with respect to science and research, Intellectual honesty and research integrity, Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP), Redundant publications: duplicate and overlapping publications, salami slicing, Selective reporting and misrepresentation of data. **(8 Lecture)**

Reference books:

1. Kothari, C R. Research Methodology Methods and Techniques (New Age International Publishers, New Delhi, 2009).
2. Ackoff, Russell L. The Design of Social Research (Chicago Press, 1961).
3. Ackoff, Russell L. Scientific Method (New work: John Wiley & Sons,1962).
4. Bird, A. (2006). Philosophy of Science. Routledge.
5. MacIntyre, Alasdair (1967) A Short History of Ethics. London.
6. P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped;ISBN:978-9387480865
7. Indian National Science Academy (INSA), Ethics in Science Education,
8. Research and Govemance (2019) , ISBN:978-81-939482-l-7
9. Pruzan and Pete. Research Methodology: The Aims, Practices and Ethics of Science
10. Fundamentals of Research Methodology and Statistics, Yogesh Kumar Singh (New Age International Publisher)

Semester 1

Course Code: PHYADL14054

Course Title: Physics Practical - I

Total Credit: 4 (0+0+4)

Duration: 48 Hours

Course Learning Outcomes: *General Physics Laboratory-I offers a number of optical and electronics practicals which enable the learners to understand the basic concept of electronic circuits through action and observation. After completion of this course, the students will have the ability to (i) understand the behaviour and operations of electronic components such as Integrated Circuit (IC), Operational Amplifier (OPAMP), Logic Gates etc. (ii) analysis and design various oscillators and electronic circuits for mathematical operations, (iii) calculate and determine self-inductance of a coil, unknown resistance of a wire etc. (iv) determine the wavelength of monochromatic light, radius of curvature of convex surface.*

List of Experiments:

1. To determine the wavelength of sodium light with the help of Fresnel Bi-prism.
2. Study the formation of Newton's rings in the air-film in between a plano-convex lens and a glass plate using nearly monochromatic light from a sodium-source and hence to determine the radius of curvature of the plano-convex lens.
3. To determine the value of an unknown resistance by using Carey-Foster bridge.
4. To determine the self-inductance of a coil using Anderson Bridge.
5. To design a Phase shift oscillator and compare its theoretical and practical frequency.
6. To design a Wien bridge oscillator and compare its theoretical and practical frequency of oscillation.
7. Using an IC 741C (a) design an integrating & differentiator circuit, (b) draw the input and output waveform, (c) measure the rise and fall time, (d) Compare the theoretical and practical value.
8. To solve a given simultaneous equation using OPAMP.

9. To design and study (a) Monostable Multivibrator, (b) Astable Multivibrator using IC555 timer.
10. To design and study Schmitt Trigger using IC 555 timer.
11. To design a CE amplifier circuit and obtain the frequency response curve of the amplifier and determine the mid frequency gain, lower and upper cut-off frequency and bandwidth of amplifier.
12. To design (a) RS flip flop (b) Gated RS flip flop and (c) D flip flop using logic circuits and verify their truth tables.

(List of practicals given above should be considered as suggestive of the standard. New practicals of similarstandard may be added and old problems may be deleted whenever considered it necessary)

Semester 2

Course Code: PHYADL14064

Paper Title: Advanced Statistical Mechanics

Total Credit: 4 (3+1+0)

Total Lecture: 48

Course Learning Outcomes: *This course gives the insight of postulates of statistical physics and calculating probability for various statistical systems of particles. After completing this course students will be able to (i) distinguish between the types of ensembles and explain the behaviour of classical and quantum statistics, (ii) establish the connection between statistics and thermodynamics, and (iii) understand the concept of the Ising model and phase transitions.*

Unit I: Classical Statistical Mechanics

Classical Statistical mechanics: Statistical basis of Thermodynamics, the micro and macro states, postulates of equal a priori probability, connection between statistical mechanics and thermodynamics. Elements of ensemble theory: Micro canonical, canonical and grand canonical ensembles, partition and grand partition functions, particle density, energy fluctuations in grand canonical ensemble, equivalence to other ensembles. **(15 lectures)**

Unit - II: Quantum Statistical Mechanics

Basic principle, inadequacy of classical theory, quantum mechanical ensemble theory, density matrix, ensembles in quantum statistical mechanics. Maxwell-Boltzmann, Bose Einstein and Fermi-Dirac statistics, properties of ideal Bose gas system and ideal Fermi gas system, their equations of state, some applications – Black body radiations, white dwarf, Bose-Einstein condensation (BEC) and experimental evidence. **(14 lectures)**

Unit - III: Fluctuations

Thermodynamic fluctuations, Gaussian distribution, random walk and Brownian motion, approach to equilibrium, Fokker-Planck equation; introduction to non-equilibrium processes.

(7 lectures)

Unit - IV: Phase transition

Formulation of the problem, the theory of Lee and Yang. First and second order phase transitions; diamagnetism, paramagnetism and ferromagnetism; Liquid Helium, Two fluid hydrodynamics, second sound, theories of Landau and Feynman. **(8 lectures)**

Unit - V: Special topics

Ising model: partition function for one dimensional case; Chemical equilibrium and Saha ionisation formula. **(4 lectures)**

Recommended Books:

1. Foundations of Statistical and Thermal Physics, F Reif, Tata McGraw-Hill, IE, 2011.
2. Introduction to Statistical Physics, Silivio R.A. Salinas, Springer, 2010.

3. Statistical Mechanics, R. K. Pathria, Paul D. Beale, Elsevier, 3rd Edition, 2011.
4. Statistical and Thermal Physics, L. D. Landau and E.M. Lifshitz, Butterworth-Heinemann; 3rd Edition, 1996.
5. Statistical Physics- An Introductory course, Daniel J Amit and Yosef Verbin, World Scientific Co Pvt Ltd, 1999.
6. Elements of Non- Equilibrium Statistics, V Balakrishnan, ANE Books- New Delhi, 2009

Semester 2

Course Code: PHYSPL15074

Paper Title: Nuclear and Particle Physics-II

Total Credit: 4 (3+1+0)

Total Lecture: 48

Course Objectives: *The aim of this course is to comprehend nuclear structure by studying collective nuclear models and nuclear reactions. It also emphasizes understanding the fundamental principles of radiation detection, while exploring significant aspects of both weak and strong interactions and the standard model.*

Course Learning Outcomes: *After learning this course, the students will be able to (i) apply the shell model and collective model to describe some basic nuclear properties, (ii) understand basics of nuclear reactions, compound nuclear reactions (iii) understand the role of symmetries in elementary particle interactions, (iv) get elementary idea of quark model, quark confinement, asymptotic freedom and standard model of particle physics*

Unit I:

Nuclear Models : (i) Shell Model: Review of shell model, Applications of shell model: Magnetic dipole moments of nucleon and nuclei - C-N Catastrophe, Schmidt's calculation of total angular momentum and total magnetic moment, electric quadrupole moments of various nuclei in the light of extreme single particle shell model. (ii) Collective Model: Failure of the nuclear shell model, Vibrational Model: Deformation parameters, Nuclear shapes with quadrupole, octupole and hexadecapole deformations, Nuclear shape vibrations, vibrational model predictions; Rotational Model: rotational energy states of a deformed nucleus. **(10 lectures)**

Unit II:

Nuclear Reaction :Different types of reactions, Direct Reaction, Kinematics of stripping and pick-up reactions, inelastic scattering. Resonance scattering and reactions: Breit-Wigner dispersion formula. Compound nucleus reaction, S. N. Ghoshal's experiment for verification of compound nuclear hypothesis. **(8 Lecture)**

Unit III:

Nuclear Radiation Detectors: General Properties of Radiation Detectors: Detector sensitivity, Energy Resolution, Detection Efficiency, Dead Time. Energy loss of charged particles: Mechanism, Stopping power and range, Bethe-Bloch formula, energy dependence of the stopping power, particle identification, Bragg curve, Radiation length. Solid State Detectors: Semiconductor detectors, Surface-barrier detectors. Scintillation counter, Solid State Nuclear Track Detectors (SSNTD). **(15 lectures)**

Unit IV:

Particle physics: The discrete symmetries C, P and T. the θ-τ puzzle, Parity violation in weak interaction: Wu experiment, CPT theorem, Quark model, Properties of quarks and their classification, Color degree of freedom, Elementary ideas of SU(2) and SU(3) symmetry groups, Gell-Mann – Okubo mass relation, Introduction to Standard Model, quark confinement, asymptotic freedom. **(9 Lectures)**

Recommended Books:

1. Introductory Nuclear Physics – Kenneth S Krane
2. Nuclear Physics (Vol.2) – SN Ghoshal
3. Radiation Detection and Measurement - Glenn F. Knoll
4. Techniques for Nuclear & Particle Physics Experiments – WR Leo
5. Introduction to Nuclear & Particle Physics –A Das & T Ferbel.
6. Nuclear Radiation Detectors- S.S. Kapoor & V.S. Ramamurthy
7. Introduction to Elementary Particles – David Griffiths
8. Nuclear and Particle Physics: An Introduction – B.R. Martin
9. Concepts of Nuclear Physics – Bernard L Cohen
10. Nuclear Physics: Theory and Experiment, – Roy and Nigam.
11. Introduction to Nuclear Reactions – GR Satchler
12. Nuclear Physics – Principles & Applications (John Lilley)
13. Nuclear & Particle Physics – WE Burcham & M Jobes.
14. Physics & Engineering of Radiation Detection, S. N. Ahmed (Academic Press 2007)

Semester 2

Paper Title: Condensed Matter Physics-I

Paper Code: PHYSPL15084

Credit: 04 (3+0+1)

Total Lecture = 48

Course Objective: *The objective of the course is to provide students with a comprehensive understanding of condensed matter physics, covering crystal structures, band theory in solids, semiconductors, phonon dynamics, and optical properties.*

Course Outcome: *On successful completion of this course, the students will develop strong foundation on (i) Students will review the fundamental elements of crystallography and learn about the free electron gas model, (ii) Students will develop an understanding energy bands in solids and fundamentals intrinsic and extrinsic semiconductors, their carrier dynamics,* *and related effects (iii) Students will learn about phonon spectra and scattering processes and understand the optical properties of materials and related phenomena.*

Unit I:

Crystal physics & free electrons in crystals: Review of elements of crystallography and crystal structures, symmetry operations, point groups and space groups, Imperfection in solids. **(8 Lectures)**

Introduction to free electron gas model. Free electron gas in one- and three-dimensional potential well, Density of states, The Fermi-Dirac distribution function. The electronic specific heat. Electrical conductivity of metals. Thermal conductivity of metals.
(8 Lectures)

Unit II:

Energy band theory:: The Bloch Theorem. The Kronig-Penny model. Brillouin zones. Energy vs Wave vector (E-K) diagram. Effective mass of an electron. Distinction between conductor, semiconductor and insulator. **(10 Lectures)**

Unit III:

Semiconductors: Intrinsic and Extrinsic semiconductors, Carrier concentration in intrinsic and extrinsic semiconductors. Fermi level and variation of carrier concentration with temperature, Law of mass action. Conductivity and mobility of semiconductors. Generation and recombination. Hall Effect. **(9 Lectures)**

Unit IV:

Phonon Spectrum: Phonon creation and annihilation operators, elastic scattering of electrons, inelastic scattering by phonons, inelastic scattering of neutrons by phonons, phonon scattering: normal and umklapp processes. **(6 Lectures)**

Unit V:

Optical properties of materials: Optical constants, Drude model, dispersion relation of optical constants from Maxwell's equations, Optical absorption and emission in semiconductors, Exciton absorption, Impurity and interband transitions, Luminescence, direct and indirect luminescence Activators, Photoluminescence and thermo-luminescence. Absorption process, Photoconductivity, photoelectric and photovoltaic effect. **(8 Lectures)**

Reference Books

1. Introduction to Solid State Physics, Charles Kittel (Wiley India Edition, 2019)
2. Solid State Physics, S.O. Pillai (NEW AGE International Pvt Ltd, 2022)
3. Solid State Physics, M.A. Wahab (Narosa Publishing House Pvt. Ltd. New Delhi, 2015)
4. Solid State Physics, A.J Dekker, (Laxmi Publications, 2008)
5. Elements of Solid State Physics, J.P. Srivastava (PHI, 2008)
6. Introduction to Solids, Leonid V. Azaroff (McGraw Hill Education, 2017)
7. Solid State Physics, N.W. Ashcroft and N.D. Mermin (Cengage, 2003)
8. Solid-state Physics, H. Ibach and H. Luth, (Springer, 2009)
9. Solid State Physics, Rita John, (McGraw Hill, 2014)
10. Solid State Physics, M.A. Wahab, (Narosa Publications, 2011)

Semester 2

Paper Title: Advance Optics-I

Paper Code: PHYSPL15094

Credit: 04 (3+1+0)

Total lectures: 48

Course Objective: *The objective of the course is to familiarise the students with optical phenomena, different concepts related laser physics*

Course outcome: *After successfully completing the course, student will be able to:*

Understand phenomenon of interaction of electromagnetic radiation with matter

Understand the lasing mechanism, types of Lasers, characteristics of Laser Light,

Understand and appreciate the applications of Lasers in various fields.

Familiarize with recent developments in Laser Spectroscopy

Have the idea of optical fibres, their properties and principle of propagation of electromagnetic waves through optical fibres

Unit I:

Interaction of Matter-radiation: Various spectroscopic techniques (Overview), absorption, spontaneous and stimulated emission of radiation, Einstein's coefficients, Coherent properties of radiation fields, Transition probabilities- weak and strong field approximation, Cavity radiation-counting the number of cavity modes, Plank's law for cavity modes, widths and profiles of spectral lines, overview of spectroscopic instrumentations-detection of light, interferometers, photo emissive detectors. **(Lecture 12)**

Unit II:

Basics of Lasers: Basic elements of lasers, saturation intensity, growth factor, properties of lasers- directionality, intensity, monochromaticity, coherence, light amplification, Population inversion, Pumping schemes, three and four level systems, threshold condition for laser oscillation, laser amplifiers, spectral characteristics, laser rate equations, laser resonators- longitudinal and transverse cavity modes. **(Lecture 13)**

Unit III:

Types and applications of Lasers: Types of lasers with examples: solid state, gas laser, Dye laser, and semiconductor lasers, liquid and chemical lasers, free-electron lasers, excimer lasers, X-ray laser, applications of lasers- Physics, Chemistry, Environmental Research, Material Science, Biology, Medical Science, communication, Atmospheric optics, industry, Holography. **(Lecture 11)**

Unit -IV:

Fibre optics: Introduction to fiber optics, Physics of light. Principles of fiber optics: Introduction, light propagation, Skew rays, meridional, optical fibre waveguides (step index, graded index, single mode), acceptance angle, numerical aperture, Signal distortion in optical fibers- Attenuation, Absorption, Scattering, Bending losses and joint losses, Core and

Cladding losses. Information capacity, Group delay, Dispersion - Material dispersion, Wave-guide dispersion, Intermodal dispersion, Fiber Birefringence, Polarization Mode Dispersion, couplers and connectors.**(lectures: 12)**

Recommended Books:

1. Principles of Lasers, O Svelto, Springer

2. Lasers and Non-linear Optics, B B Laud, New age international limited, publishers

3. Elements of Laser and Non-Linear Optics, G D Baruah, Prakashan, Meerut

4. Optical Fiber Communications Principles and Practice − John M. Senior, M. Yousif Jamro, Pearson

Semester 2

Course Code: PHYSPL15104

Course Title: Physics Practical - II

Total Credit: 4 (0+0+4)

Duration: 48 Hours

Course Learning Outcomes: *Physics Practical-II course is focusing on advanced techniques and experiments drawn from overall physics classes consisting of advanced electronics, solid state physics, nuclear physics and optics. The student will be able to grasp the role of experimental design, data analysis, error analysis, and the use of computers while investigating physical phenomena.*

List of experiments:

1. Design a triangular wave generator & compare its theoretical and practical frequency.
2. To Study Adder, Subtractor & Comparator circuit using IC-741 & verify theoretical and practical output.
3. Measure the resistivity & hence the band gap of a semiconductor sample with the use of four probe apparatus.
4. Determine the Hall-coecient, carrier density & carrier mobility of a given semiconductor by using Hall-coecient apparatus.
5. Using IC-741 (a) Design a 1st order & 2nd order low pass filter (b) Draw the frequency response curve (c) Find the roll o rate (d) Determine the gain & cut-o frequency theoretically and practically.
6. Verify the inverse square law for Gamma rays with the help of G.M. counter.
7. Measure the specic charge (e/m) of an electron using Helical method.
8. Determine the specic charge i.e. charge to mass ratio (e/m) of an electron using Thomson's bar magnet method.

9. Determine the value of Planck’s constant with the help of a photoelectric cell and monochromatic filter.
10. Study the bending loss in an optical fibre with dierent angles of bending of the fibre.
11. To measure the power-loss at a splice between two multi-mode fibre and study the power-loss for longitudinal and angular shift.
12. To sort a string of a number of bytes in descending/ascending order using the 8086 microprocessor.
13. Using microprocessor 8086 (a) Write a program to Add two binary numbers each 8 bytes long (b) Write a program to and maximum no. in a given string & store it in location 0310.
14. Using microprocessor 8085 (a) Write a program for Hexadecimal addition of two numbers (b) Write a program for decimal addition of two decimal numbers.

Semester 3

Course Code: PHYSPL25014

Course Title: Advanced Nuclear and Particle Physics

Total Credit: 4 (3+1+0)

Total Lecture: 48 Hours

Course Objectives: *This course aims to impart knowledge on essential aspects of gamma decay and its practical applications, while also offering foundational understanding of nuclear fission and fusion reactions. Additionally, it covers key concepts of radiation safety and explores neutrino physics, applying relativistic kinematics to particle production and decay..*

Course Learning Outcomes: *After learning this course, the students will be able to (i) apply angular momentum and parity selection rules to predict gamma transition, (ii) apply the basic principle of Mossbauer effect to measure the Isomer shift, determination of gravitational red shift. (iii) calculate important nuclear fission reactor parameters such as slowing down power, moderating ratio & diffusion length (iv) derive & solve Fermi Age Equation (v) compute fission and fusion barrier (vi) distinguish between stellar nucleosynthesis and big bang nucleosynthesis and Controlled fusion reaction (vii) Accumulate some radiological protection knowledge like effective Biological effect (RBE), shielding, Radiation safety in the laboratory for nuclear physics (viii) apply basic QM to explain the neutrino oscillation. (ix) apply relativistic kinematics in particle production and decay problems.*

Unit I: Gamma Rays

Multipole expansion of Radiation field, multipolarity, gamma-ray transition probability, Angular momentum and Parity selection rules, Nuclear Isomerism, Internal Conversion of gamma-rays; Mossbauer spectroscopy: Mossbauer effect, Experimental techniques, Applications of Mossbauer effect – Isomer shift, determination of gravitational red shift. **(8 lectures)**

Unit II: Nuclear Fission and Reactor Physics

Fission: spontaneous and induced fission, Q-value of fission, fission barrier, activation energy, condition for spontaneous fission, characteristics of fission - energy and mass distribution of fission product, number of emitted neutrons, cross-section of neutron induced fission, Bohr-Wheeler theory of fission; Reactor Physics: Sources of neutron, detection of neutrons, classification of neutrons, slowing down of neutrons, slowing down power, diffusion of thermal neutrons, Fermi Age equation, moderating ratio, fission chain reaction & multiplication factor, four-factor formula, reactor theory; Nuclear reactor programme in India. **(14 lectures)**

Unit III: Nuclear Fusion

Nuclear fusion: Basic fusion process, characteristics of fusion - Energy release, Coulomb barrier, cross-section, reaction rate, thermonuclear fusion in stars -pp chain & CNO cycle, Big Bang nucleosynthesis, nucleosynthesis beyond iron, r- and s-processes. Controlled fusion reaction, Debye length, Confinement of plasma - magnetic confinement and Toroidal confinement, Lawson criterion – Tokamak. **(8 lectures)**

Unit IV: Radiation Protection

Dosimetric units: The Roentgen, absorbed dose, relative biological effects (RBE), equivalent dose, effective dose; typical doses from sources in environment. Guiding principle of radiation safety (ALARA); Biological effects: high doses received in short time, low-level doses; dose limits; shielding; radiation safety in the nuclear physics laboratory. **(10 lectures)**

Unit V: Particle Physics

Solar and Atmospheric neutrino anomaly, neutrino oscillation, neutrino mass hierarchy, overview of neutrino oscillation experiments. Simple applications of relativistic kinematics in particle production and decay problem. Fixed target versus colliding beam experiments. **(8 lectures)**

Recommended Books:

1. Introductory Nuclear Physics – Kenneth S Krane (Wiley)
2. Atomic and Nuclear Physics (Vol. 2) – SN Ghoshal (2nd Ed. S Chand)
3. Introduction to Elementary Particles – David Griffiths (Wiley & Sons, Inc.)
4. Neutrino Physics – Kai Zuber (2nd Edn. CRC Press)
5. Techniques for Nuclear & Particle Physics Experiments – WR Leo (2nd Ed. Springer)
6. Radiation Detection and Measurement – Glenn F Knoll (4th Ed. Wiley)
7. Nuclear Moments – H. Kopferman
8. Nuclear Magnetic Resonance Spectroscopy – F. A. Bovey, P. A. Mirau and H. S. Gutowsky (2nd Edn. Academic Press)

Semester 3

Paper Title: Condensed Matter Physics-II

Paper Code: PHYSPL25024

Credit: 04 (3+0+1)

Total Lecture: 48

Course Objective: *The objective of this course is to provide students with a comprehensive understanding of the fundamental concepts and mathematical formulations of magnetic properties of solids, field of soft condensed matter physics, semiconductor devices concepts of superconductivity.*

Course Learning Outcomes: *At the end of the course, (i) the students will gain an understanding of the fundamental concepts and mathematical formulations related to magnetic properties of solids. (ii) Students will develop a comprehensive understanding of the behavior of electrons in a magnetic field, focusing on magneto-conductivity and the properties of the Fermi surface. (iii) Students will be introduced to the field of soft condensed* *matter physics. (iv) Students will gain a thorough understanding of semiconductor devices, including carrier transport phenomena and the characteristics of various junctions. (v) Students will also learn about the theory and phenomena of superconductivity and explore key concepts related to superconductivity.*

Unit I: Magnetic properties of Solids

Exchange interaction and exchange integral for a two-electron system, Heisenberg Hamiltonian for exchange interaction, relationship between exchange energy and molecular field, ferromagnetic spin waves and antiferromagnetic spin waves and their dispersion relations, magnons. **(12 Lectures)**

Unit II: Electrons in magnetic field

Magneto-conductivity, Fermi surface, cyclotron resonance, Landau levels and Landau cylinders, de Hass-Van Alphen effect. **(6 Lecture)**

Unit III: Soft condensed matter physics

Introduction to polymers, conducting polymers, biopolymers and biodegradable polymers, Liquid crystal, Van der Waals interaction and forces, colloidal dispersion. **(5 Lectures)**

Unit IV: Semiconductor devices

Carrier transport phenomena in semiconductors, Junctions: p-n junction in equilibrium, contact potential, space charge at the junction, forward and reverse biasing, p-n junction capacitance: depletion and charge storage capacitance, I-V characteristics; Metal-semiconductor junctions: Ohmic and Schottky junction, semiconductor homo and heterojunctions. **(12 Lectures)**

Unit I: Superconductivity

Thermodynamics of superconducting state, Type-I and Type-II superconductors, Meissner effect, London equations, Isotope effect, Frohlich interaction, London equation, BCS theory of superconductivity, flux quantization, Giaever tunneling and Josephson effects (d.c. and a.c.), superconducting quantum interference device (SQUID), Ginsburg-Landau theory, introduction to high temperature superconductors. **(13 Lectures)**

Reference Books

1. Introduction to Solid State Physics, Charles Kittel (Wiley India Edition, 2019)
2. Solid State Physics, S.O. Pillai (NEW AGE International Pvt Ltd, 2022)
3. Solid State Physics, M.A. Wahab (Narosa Publishing House Pvt. Ltd. New Delhi, 2015)
4. Physics of Semiconductor Devices, S.M. Sze and Kwok K. Ng (Wiley India, 2015)
5. Solid State Electronic Devices, Ben. G. Streetman and S. K. Banerjee (Pearson Education India; 2015)
6. Introduction to Superconductivity, Michael Tinkham (Medtech; Standard Edition, 2017)

7. Superconductivity, SL Kakani and Shubhra Kakani (NEW AGE International Pvt Ltd, 2020)
8. I. W. Hamley, Introduction to Soft Matter, (Wiley, Chichester, 2000).
9. R. A. L. Jones, Soft Condensed Matter, (OUP, Oxford, 2002).

Semester 3

Course Code: PHYSPL25034

Course Title: Experimental Techniques in Physics

Total Credit: 4 (3+1+0)

Total Lecture: 48

Course Objective: *The aim of this course is to implement tools and techniques used by experimental physicists in the laboratory. Students will learn to analyze various error systems, industrial equipment's working principle and applications and insight into the preparation of nanomaterials.*

Course Outcome: *This course will provide a basic understanding about the scientific research and various techniques. After completion of the course, students will be able to familiarize with various research methodologies to address the contemporary research problems, investigate the data by using different scientific techniques.*

Unit I: Error Analysis and Numerical Methods:

Uncertainties in measurement: measuring errors, uncertainties, parent & sample distributions, mean & standard deviation; Probabilities distributions: binomial, Poisson, Gaussian, & Lorentzian distribution; Error analysis: instrumental & statistical uncertainties, propagation of errors; Estimates of mean & errors: statistical fluctuations, probability tests, reliability test of a distribution; Least-Squares Fit: Method of Least Squares χ & uncertainties in parameters, Limitations of the Least-Squares Method; Maximum likelihood. **(12 lectures)**

Unit II: Synthesis of thin solid films and nanomaterials

Thin Films, different methods of thin film preparation and nanomaterials: chemical and physical route, evaporation, sputtering, pulse laser deposition, lithography, solgel, hydrothermal, chemical bath deposition, spray pyrolysis, condensation, nucleation and growth. **(12 Lectures)**

Unit III: Material characterization tools and techniques

x-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM), scanning tunnelling microscopy (STM),Optical properties using UV-Vis spectrometer, Photoluminescence. **(10 lectures)**

Unit IV: Advanced nuclear techniques

Nuclear Magnetic Resonance (NMR): Resonance condition, Experimental technique – Purcell and Bloch method, Applications of NMR – Determination of nuclear spin, Chemical shift.

Nuclear Electronics: Overview of pulse processing, pulse pile-up,electronic noise, baseline shift, triggers, Preamplifiers - voltage & charge sensitive configurations, noise characteristics, detector bias voltage. Pulse shaping; Pulse counting: Discriminator, scalars or counters; Pulse height analysis, Linear amplifier, ADC, TDC, MCA, Coincidence; Background and Detector Shielding: Sources of background, background in different detectors, Shielding materials, active methods of background reduction. **(14 lectures)**

Reference Books:

1. Research Methodology: Methods and Techniques – C. R. Kothari (Newage Publishers)
2. Data Reduction and Error Analysis for the Physical Sciences – P.R. Bevington and K. D Robinson (McGraw Hill, 2003)
3. Thin film Fundamentals –A Goswami
4. Thin film Phenomena – K L Chopra
5. Elements of X-ray diffraction – B D Cullity
6. Cryogenics Systems – R. F. Barron (2nd Edition, Oxford university Press 1985)
7. Nanotechnology: Principles and Practices – Sulbha Kulkarni (Springer)
8. Introduction to Nanotechnology – Jr. C. P. Poole, and F. J. Owens (Wiley)
9. Nanostructures and Nanomaterials: Synthesis, Properties and Applications - Guozhong Cao (Imperial College Press, 2004)
10. Radiation Detection and Measurement – Glenn F Knoll (4th Ed. Wiley)
11. Techniques for Nuclear & Particle Physics Experiments – WR Leo (2nd Ed. Springer)

Semester 3

Course Code: PHYSPL25044

Course Title: Computational Physics

Total Credit: 4 (3+1+0)

Total Lecture: 48

Course Objectives: *Learning basic methods, tools, and techniques of computational physics and developing practical computational problem-solving skills.*

Course Learning Outcomes: *After learning this course, the students will be able to (i) solve nonlinear equations such as Bisection method, regula-falsi method, Newton Raphson method and Secant method. (ii) solve system of linear equations using both Gauss elimination and Gauss-Jordan method with and without pivoting, (iii) perform polynomial interpolation such as Newton-Gregory and lagrange interpolation method and least square curve fitting (iv) compute numerical integration using trapezoidal rule, Simpson's one third rule in Monte Carlo method (v) solve first and second order linear differential equation using Euler method and Runge-kutta method.*

Part – I : Numerical Methods (Theory)

Unit - I Introduction

Introduction to computational physics, computer architecture overview, tools of computational physics, Integer representation; floating-point representation on a computer, Errors: round off and truncation errors. **(3 lecture)**

Unit - II: Solution to nonlinear equations

Bisection method, Regula-Falsi Method, Newton-Raphson method, Secant method, advantages and disadvantages, errors in each of these methods. **(3 lectures)**

Unit - III: Solution of linear systems

Gauss elimination and Gauss-Jordan elimination, pivoting. **(3 lectures)**

Unit - IV: Interpolation and curve-fitting

Polynomial interpolation using Lagrange's method, construction of Newton-Gregory forward difference and backward difference tables, error estimation in these methods, curve-fitting and the principle of least square. **(5 lectures)**

Unit - V: Numerical Integration:

Integration by trapezoidal and Simpson's rule, Montecarlo integration. **(5 lectures)**

Unit - VI: Solution of differential equations

Euler's method for solving first order linear differential equations (initial value problem): limitations and discussion on its accuracy, Runge-Kutta method and its comparison with Euler's method, 4th order R-K method. **(5 lectures)**

Part – II : Computational Lab

1. Introduction to Linux and Computer Programming Language (FORTRAN /C++ / Python), Plotting with GNUPLOT/Matplotlib.
2. Solution of nonlinear equations: Bisection Method, Regula-Falsi Method, Newton-Raphson Method, Secant method.
3. Interpolation: Newton interpolation, Lagrange interpolation
4. Curve fitting and regression: Least squares fitting, polynomial curve fitting
5. Numerical integration: Trapezoidal rule, Simpson’s rule, Gaussian quadrature method
6. Differential equation: Solution of 1st and 2nd order differential equation using Euler’s and Runge-Kutta method: Simple harmonic oscillator problem with and without damping effects, Solution of Schrodinger’s equation under various standard potentials. Boundary value problems: Shooting method. Solution of partial differential equations (PDEs) with finite difference method.
7. Matrix methods: Determination of Eigenvectors of a system of linear equations, Finding eigenvalue and corresponding eigenvector, Solution of linear systems of equations through matrix inversion.
8. Monte Carlo Technique: Generation of random numbers, Monte Carlo evaluation of integrals, determination of the value of π. Monte Carlo technique to simulate nuclear decay phenomena, Simulation of random physics phenomena, Brownian Motion.

(List of programming given above should be considered as suggestive of the standard. New problems of similar standard may be added and old problems may be deleted whenever considered it necessary)

Recommended Books:

1. Introductory Methods of Numerical Analysis –S. S. Sastry (PHIL Pvt. Ltd.)
2. Numerical Methods –E. Balagurusamy (McGraw Hill Ed.)
3. Computer Oriented Numerical Methods –V. Rajaraman (PHIL Pvt. Ltd.)
4. Numerical Recipes –W. H. Press (Cambridge University Press)
5. Programming with C++ – Ravichandran (McGraw Hill Ed.)
6. Schaum's Outline of Programming with C++ – John Hubbard (McGraw Hill Ed.)

Semester 3

Course Code: PHYSPL15104

Course Title: Physics Practical - III

Total Credit: 4 (0+0+4)

Duration: 48 Hours

Condensed Matter Physics:

Course Learning Outcomes: *This course offers the advanced hand on experiments of advanced condensed matter physics. After completion of this course students will have a deeper understanding on the subject and they will be able to understand the phenomena practically.*

List of Experiments:

1. To determine the Lande g-factor of electrons by using the ES set up.
2. To study the temperature dependence of Hall coecient.
3. To determine magnetoresistance of the supplied material.
4. To determine the (i) Susceptibility arising due to water in the solution of MnCl2 (ii)
1. magnetic moment of Mn++ ions in terms of Bohr magneton and (iii) the ionic molecular
2. susceptibility of Mn++ ions by using Quink's method.
5. To study the I-V characteristics of the supplied solar cell and nd its spectral response.
6. To determine the transition temperature of the supplied ferroelectric materials (BaTiO3).
7. To determine the power law dependence of photocurrent on intensity of illumination in a thin lm sample.
8. To measure the transmission and absorption coecients of a given liquid and a solid thin lm with spectrophotometer.
9. To study the thermoluminescence of F-centres of alkali halides.

Nuclear Physics:

Course Learning Outcomes: *After learning this course, the students will be able to (i) Use GM counter in order to calculate the dead time and efficiency of the counter, (ii) use scintillation counter and analyze various peaks using single and multi channel analyzer, (iii) handle microscope (a) to calculate the average diameter of α-particle tracks, (b) will able to scan nuclear emulsion plates and can calculate mass of pion, scattering cross section, and range of tracks.*

List of Experiments

1. To determine the dead time of a GM counter using a single source.
2. To determine the eciency of a G.M. counter for β and γ-rays.
3. To study the absorption of beta rays emitted from dierent radioactive sources in Al, and hence to nd the range-energy relation for beta particles by Feather's method.
4. (a) To study the complete spectrum of dierent gamma sources and to locate the corresponding photo peak, Compton edge, using NaI (Tl) scintillation counter and single channel analyzer (SCA) and draw calibration curve. (b) To nd the resolution R for dierent energies and hence to draw log vs. logE curve.
5. To study the complete spectrum of dierent gamma sources and to locate the corresponding photo peak, Compton edge, using NaI (Tl) scintillation counter and Multi channel analyzer (MCA).
6. (i) To study the complete spectrum of Mn-54, using NaI (Tl) scintillation counter and multichannel analyser. (ii) To calibrate and determine the resolution R using the sources Cs-137, Ba-133 and Co-60 taking Na-22 as the unknown source.
7. To create the rough vacuum in a given small stainless steel chamber and nd out the resolution of an SSB detector inserting inside it using a 241Am α-source.
8. To determine the average diameter of α-particle tracks in SSNTD.
9. To study the "Thorium stars" produced in the nuclear emulsion and to measure the range of the tracks and to draw energy histograms.
10. To determine the mass of the pion by studying π-μ decay in nuclear emulsion.
11. (i) To scan a given nuclear emulsion plate to determine the number of prongs of the stars. (ii) To draw the Nn distributions of the interaction stars and hence calculate the excitation energy of the interaction. (iii) To determine the scattering cross-section for interaction.

1. To measure the excitation potential of mercury using the Franck-Hertz method.
2. To study the emission spectra of Hydrogen (Balmer series) and determination of Rydberg's constant
3. To determine the wavelength of He-Ne laser light.
4. To study Zeeman effect and determination of Bohr magneton
5. To determine the wavelength of light from a monochromatic source using interferometer and then to determine the difference of wavelength for Sodium D lines.

(List of practicals given above should be considered as suggestive of the standard. New practicals of similar standard may be added and old experiments may be deleted whenever considered it necessary)

Semester 4

Course Code: PHYSPL25064

Course Title: Plasma Physics

Total Credit: 4 (3+1+0)

Total Lecture: 48

Course Objectives: *Plasma physics is a multidisciplinary and essential subject for a large number of research fields, including controlled thermonuclear fusion, space plasma physics, solar physics, astrophysics, high-power laser physics, plasma processing, and many areas of experimental physics. The primary learning outcome for this course is for the students to learn the basic principles and main equations of plasma physics, at an introductory level, with emphasis on topics of broad applicability.*

Course Learning Outcomes: *On completion of the course the student shall be able to: Define, using fundamental plasma parameters, under what conditions an ionised gas consisting of charged particles (electrons and ions) can be treated as a plasma. Distinguish the single particle approach, fluid approach and kinetic statistical approach to describe different plasma phenomena. Classify the electrostatic and electromagnetic waves that can propagate in magnetised and non-magnetised plasmas, and describe the physical mechanisms generating these waves. Define and determine the basic transport phenomena such as plasma resistivity, diffusion (classical and anomalous) and mobility as a function of collision frequency and of the fundamental parameters for both magnetised and non-magnetised plasmas. Formulate the conditions for a plasma to be in a state of thermodynamic equilibrium, or non-equilibrium, and analyse the stability of this equilibrium and account for the most important plasma instabilities. Explain the physical mechanism behind Landau damping and make calculations in this area using kinetic theory.*

Unit I: Introduction to plasma-charge particle motion

Definition and properties of plasma, Plasma production in laboratory and diagnostics. Microscopic description, Motion of a charged particle in electric and magnetic fields-curvature, gradient and external force drifts. **(12 lectures)**

Unit II: Plasma production and devices

Laboratory production methods and confinement schemes, Controlled thermonuclear devices, magnetically confined open and closed systems (linear pinch, mirror machine and Tokamak). Laser-plasmas: inertially confined system. **(7 Lectures)**

Unit III Statistical description of plasmas

B.B.G.K.Y. hierarchy of equations, Boltzmann-Vlasov equation, Equivalence of particle orbit theory and the Vlasov equation, Boltzmann and landau collision integral H-theorem, B.G.K. model, Fokker-Planck term, Solution of Boltzmann equation (brief outline), Transport coefficient-electrical conductivity, diffusion. **(16 Lectures)**

Unit IV: Waves and Instabilities

Small amplitude plasma oscillations. Oscillations in warm field free plasma. Landau damping. Nyquist method-Penrose criterion of stability. Two stream stability (linear and quasi linear theory). Vlasov theory of magnetized plasma. Loss cone instabilitly. Quasilinear theory of gently bump instability. Non-linear electrostatic waves, BCK waves. **(13 Lectures)**

Reference Books:

1. Introduction to Plasma Physics, F. F. Chen (Plenum Press, 1984)
2. Principles of Plasma Physics, N. A. Krall and Trivelpiece (San Fransisco Press, 1986)
3. Physics of High temperature Plasmas, G. Schimdt (2ndEd., Academic Press, 1979)
4. The framework of Plasma Physics, R.D. Hazeltine & F.L. Waelbroeck (Perseus Books, 1998)
5. Introduction to Plasma Physics, R.J. Goldston and P.H. Rutherford (IOP, 1995)
6. Fundamentals of Plasma Physics, J. A. Bittencourt (Springer Science & Business Media, 2013)
7. Fundamentals of Plasma Physics, Paul M. Bellan, (Cambridge University Press 2008)

Semester 4

Course Code: PHYSPL25074

Course Title: Advanced Optics-II

Total Credit: 4 (3+1+0)

Total Lecture: 48

Course Objective: *The objective of the course is to familiarise the students with non-linear optical phenomena as well as various concepts related laser physics*

Course Outcomes*: At the end of the course, the students will be able to*

Learn the basic principles of non linear spectroscopy

Familiarize with principles and instrumentations in non linear spectroscopy

Learn the different techniques of laser Raman spectroscopy and applications

Familiarize with recent developments in Laser Spectroscopy

Unit I: Nonlinear Optics

Nonlinearities of the polarization, generation of second harmonic, D.C., sum and difference frequency generation, anharmonic oscillator model, Miller's rule, crystal symmetry, coupled amplitude equations, Manley-Rowe relation. **(Lecture 10)**

Unit II: Phase Matching

Basic idea of phase matching, quasi-phase matching method, various methods of phase matching, critical and noncritical phase matching, collinear and non-collinear phase matching, expression of angle band-width ($\Delta\theta$) and wavelength band-width ($\Delta\lambda$) in phase matched second harmonic generation, idea of tangential phase matching. **(Lecture 11)**

Unit III: Second Harmonic Generation Basic equation, conversion efficiency and parameters affecting doubling efficiency, various methods of enhancing conversion efficiency, second harmonic generation with Gaussian beam, intra cavity second harmonic generation. **(Lecture 10)**

Unit IV: Higher Order Nonlinear Processes

Four wave mixing processes-third harmonic generation, resonance enhancement of nonlinear susceptibilities, Nonlinear Raman spectroscopy- stimulated Raman scattering, Coherent Anti-Stokes Raman Spectroscopy (CARS), hyper Raman effect, inverse Raman scattering, photo-acoustic Raman spectroscopy, Applications of Laser Raman Spectroscopy. **(Lecture 9)**

Unit V: Time resolved laser spectroscopy

Q-switched lasers, mode locking of lasers, laser amplifiers, femtosecond pulses, measurement of ultrashot pulses, life-time measurements with lasers, pump and probe techniques. **(Lecture 8)**

Recommended Books

1. Lasers and Non-linear Optics, B B Laud, New age international limited, publishers
2. Principles of Lasers, Orazio Svelto, Springer
3. Elements of Laser and Non-Linear Optics, G D Baruah, Prakashan, Meerut
4. Tunable Lasers and Applications, A. Mooradian.T.,Jaeger and P. Stockseth
5. Tunable Solid State Lasers-II, A.B. Budgor, L. Esterowitz and L.G. Deshazer

Semester 4

Course Code: PHYSPL25084

Course Title: Vacuum Science and Technology

Total Credit: 4 (3+1+0)

Total Lecture: 48

Course Objectives: *This course provides the complete understanding of vacuum technology and vacuum measurements systems.*

Course Outcomes: *After learning this course students will have the knowledge about vacuum system, different ranges of vacuum creation system and mechanism and various vacuum measurement systems. At the end of the course, the students will be able to design and construct vacuum system to create high vacuum.*

Unit – I: Vacuum Science

Kinetic theory of gases: Atomistic concept of gas pressure and temperature, Molecular distribution functions, Impingement rate of molecules on a surface, Free path of gas molecules, Gas viscosity and flow, gas conductance of a vacuum line, gas impedance of a vacuum line, flow of gases through apertures, elbows, tubes etc. for viscous and molecular flow regimes. **(14 Lectures)**

Unit - II: Production of Vacuum

Meaning of vacuum and vacuum measuring units, vacuum ranges, pumping speed and pump down time. Explain the different ranges of pressure, Principles of pumping concept, Types of vacuum pumps and their working principle: Mechanical pumps (Oil sealed rotary pump, Roots Pump), Molecular drag, Diffusion, Cryogenic, Getter, Titanium sublimation, Sputter ion pump. **(14 Lectures)**

Unit-III: Vacuum Measurements

Understand different types of pressure gauges and their operating principles, Vacuum Gauges: Mc Leod, Thermocouple, Pirani, Penning, Hot cathode ionization (triode type), Vacuum system design and its operation steps. **(12 Lectures)**

Unit – IV: Applications of Vacuum Technology

Applications in science, technology, research, space science, medical science, day to day life. Vacuum system and components for electronics, metallurgy, chemical and nuclear fields. **(8 Lectures)**

Reference books:

1. Hand book of Thin Film Technology, L. I. Maissel and R. Glang, McGraw Hill Book Co. 1970, 07-039742-2
2. Vacuum Physics and Techniques, T. A. Delchar, Chapman and Hall (Springer)
3. Vacuum Technology, A. Roth, (North Holland, Elsevier Science B.V. 1990)
4. High Vacuum Techniques, J. Yarwood, (Chapman and Hall, London, 1967)
5. Online resources can be used for reference.

Semester 4

Paper Title: Nanoscience and Nanotechnology

Paper Code: PHYSPL25094

Credit: 04 (3+1+0)

Total Lecture: 48

Course Objective: The objective of this course is to provide students with a comprehensive understanding of nanoscience, nanotechnology, and its applications.

Course Learning Outcomes: *At the end of the course, (i) The students will be able to gain an understanding of the fundamental principles of the nanoscale regime, (ii) Students will learn the promising area of nanomaterials, understand the nature and prospects for the field. (iii) Students learn about the various types of nanomaterials such as semiconducting nanomaterials, carbon based nanomaterials thin solid films, (iv) Students will delve into the concept of quantum confinement and its implications for nanostructured materials and explore the diverse potential applications of nanomaterials in various fields, (v) Students will develop an understanding of nanomagnetism and learn about thin solid films technologies and their properties.*

Unit I:

Concept of nanoscale regime, Emergence of nanotechnology, Bottom up and top down approaches, Challenges of nanotechnology. **(4 Lecture)**

Unit - II: Introduction to nanostructured materials

Metal-oxide nanoparticles, nanorods and nanotubes; core-shell nanostructures: inorganic-inorganic, inorganic-organic, organic-organic and polymer-inorganic core shell structures; metal nanostructures; carbon fullerenes and single and multi-walled carbon nanotubes; micro and mesoporous materials: ordered mesoporous structure, random mesoporous structure, zeolites; Nanostructure fabrication techniques, Morphological studies of nanostructures. **(12 lectures)**

Unit III:

Idea of nano-structured materials; Quantum confinement: Quantum well Quantum dots and quantum wires, Density of states, Brus Equation: Effective bandgap of QDs, Opto-electronic properties of semiconductor nanomaterials, Structural properties of nanomaterials. **(10 lectures)**

Unit IV: Potential applications of nanomaterials

Nanoelectronics, Biological applications of nanoparticles, Band gap engineered quantum devices, Photonic crystals. **(4 Lecture)**

Unit V: Nanomagnetism

Origin of nanomagnetic behaviour, magnetic anisotropy, magnetic domain structure and magnetism in ferromagnetic nanomaterials, superparamagnetism. Spin dependent scattering. **(6 Lectures)**

Unit VI: Thin Solid Films

Thin films and preparation by physical and chemical methods, Condensation, nucleation and growth of thin films, size effect in electrical conductivity: Fuchs and Sondheimmer theory and comparison with experiments; Two-dimensional electron gas (2DEGS) systems, 2DEGS in hetero-structures, integral quantum hall effect (QHE) and fractional quantum hall effect. **(12 Lectures)**

Reference Books

1. Nanostructures and Nanomaterials, Guozhon Cao (World Scientific, 2011)
2. Nanotechnology: Principles and Practices, Sulbha Kulkarni (Springer, 2014)
3. Introduction to Nanotechnology, Jr. C. P. Poole, and F. J. Owens (Wiley, 2008)
4. Principles of Nanomagnetism, Alberto P. Guimarães (Springer, 2012)
5. Thin Film Fundamntals, A .Goswami (New Age International, 1996)
6. Thin Film Phenomena, Kasturi Lal Chopra (Krieger Pub Co., 1979)

Semester 4

Paper Title: Literature Survey on Research Topic

Paper Code: PHYSPL25104

Credit: 04 (0+0+4)

Total Lecture: 48

Course objective: *The literature review research course aims to equip M.Sc. students with the essential skills and knowledge required to critically analyze, synthesize, and evaluate existing scholarly literature within their respective fields of study.*

Course outcome: *After completion of the course Students will learn to identify key research themes, methodologies, and theoretical frameworks relevant to their research interests, fostering a deep understanding of the current academic discourse. Furthermore, students will have developed the proficiency to construct coherent and insightful literature reviews that lay the foundation for their own research endeavors, demonstrating advanced scholarly inquiry and engagement with contemporary academic scholarship.*

Guidelines:

1. Student has to do the literature survey on any research topic in physics and submit a report.

2. Student has to give a seminar presentation on the selected topic for both internal and final evaluation.