BODOLAND UNIVERSITY

Syllabus for
1 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

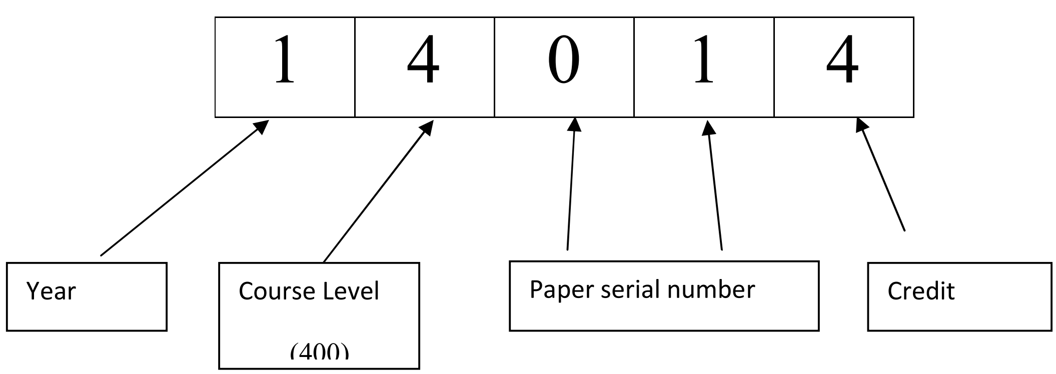
REM: Research Methodology

ADL: Advance Learning

SPL: Specialized Learning

RES: Research

Digit Explanation example:



Curriculum Structures
for
1 Year PG Programme

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 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.

****