MANGALDAI COLLEGE

(Autonomous)



PG SYLLABUS

Effective from Session: 2026-27

Mangaldai College (Autonomous)

Subject: Physics

Two Year Post Graduate Programme in Physics Semester -I
Paper Name: Mathematical Physics-II
Paper Code: PHY-CC-201014
Total number of contact hours: 60 (45 L + 15 T)
Total credits: 4 (Theory 3 + Tutorial 1)
Total Marks: 100 (60 (Th) + 40 (Int))

Course Outcomes:

CO 1: Explain linear vector spaces, inner products, operators and matrix methods.

CO 2: Apply tensor algebra and tensor calculus to problems in physics.

CO 3: Use Laplace and Fourier transforms to solve differential equations.

CO 4: Analyze finite groups, representations and character tables.

CO 5: Relate Lie groups and Lie algebras to symmetry problems in physics.

Contents:

Unit-I: Linear Vector Spaces and Matrix Methods (11 L + 4 T)

Linear vector spaces: definition, properties, linear independence, basis and dimension; inner and outer products, Hilbert space, orthogonality and Gram-Schmidt orthogonalization. Linear operators and their algebra; projection operators, completeness relation and matrix representation. Parametrization of special matrices; change of basis, diagonalization, spectral theorem for Hermitian matrices, Cayley-Hamilton theorem and singular value decomposition. Direct product/tensor product of two vector spaces ($V \otimes W$).

Unit-II: Tensor Algebra (5 L + 1 T)

Introduction to tensors; transformation of coordinates; Einstein's summation convention. Contravariant, covariant and mixed tensors. Symmetric and antisymmetric tensors, Kronecker delta, Levi-Civita tensor. Quotient law of tensors. Rules of combination of tensors: addition, subtraction, outer multiplication, contraction and inner multiplication.

Unit-III: Tensor Calculus (11 L + 4 T)

Differentiable manifolds and coordinate systems; transformation of coordinates: Galilean and Lorentz transformations in tensorial language; tangent vectors and gradients; metric tensor in different curved spaces. Four-vectors and physical examples from special relativity and electrodynamics; Christoffel symbols, covariant derivatives and parallel transport; geodesics. Idea of curvature.

Unit-IV: Integral Transformations (7 L + 2 T)

Laplace transform and inverse Laplace transform. Fourier transform. Shifting theorem and convolution. Solution of differential equations with the help of Laplace and Fourier transform.

Unit-V: Group Theory (11 L + 4 T)

Group axioms and examples; finite groups, cyclic groups Zn, permutation groups S_2, S_3, and $D_3 \simeq S_3$, multiplication tables, subgroups, cosets and conjugacy classes. Direct and semi-direct products. Representations of groups; reducible and irreducible representations, block diagonalisation, Schur's lemma, characters and character tables; decomposition of reducible and product representations. Lie groups: SU(2) and SO(3); related generators and Casimir operators; Lie algebra.

Reference Books:

1. Mathematical methods for physicists, Arfken and Weber.
2. Mathematical Physics, P. K. Chattopadhyay.
3. Matrices and tensors in Physics, A. W. Joshi.
4. Mathematical methods in the Physical Sciences, Mary L. Boas.
5. Mathematics for physicists, P. Dennery and A. Krzywicki.
6. Mathematical Physics: with applications, problems and solutions, V. Balakrishnan.
7. Introduction to Relativity, J. V. Narlikar.
8. Mathematical Physics, A. G. Ghatak, I. C. Goyal and S. J. Chua.
9. Group Theory: A Physicist's Survey.
10. Group Theory for Physicists with Application, P. Ramadevi and V. Dubey.
11. Symmetries in Quantum Mechanics, M. Chaichian and R. Hagedorn.

Two Year Post Graduate Programme in Physics
Semester -I
Paper Name: Quantum Mechanics-II
Paper Code: PHY-CC-201024
Total number of lectures: 45 L
Total credits: 4 (Theory 3 + Pract 1)
Total Marks: (45 (Th) + 25 (Pract) + 30 (Int))

Course outcomes:

CO 1: Interpret and apply the concepts of superposition of states, Bra and Ket vectors algebra, and orthonormal conditions in quantum mechanics.
CO 2: Apply perturbation theory, variational method, and time-dependent perturbation theory to analyze quantum systems and evaluate their limitations.
CO 3: Illustrate space and time translations, rotational invariance, and angular momentum operators.
CO 4: Analyze combinations of wave functions, exchange degeneracy, and quantum statistics for systems of identical particles.
CO 5: Examine and conclude the act of measurement and quantum harmonic oscillator.

Contents:

Unit-I: Matrix formulation of quantum mechanics *(16 L)*

Quantum states and linear algebra, superposition of states, act of measurement, Bra-Ket vectors and applications, orthonormal and completeness conditions, Hermitian operators, simultaneous eigen states, expectation values, change of basis, linear harmonic oscillator. Heisenberg's uncertainty principle in matrix mechanics. Heisenberg's equation of motion and physical equivalence of Schrödinger & Heisenberg picture.

Unit-II: Identical particles *(6 L)*

Indistinguishability, combinations of wave functions for a system of particles, symmetric and antisymmetric wave functions, spin-statistics connection, evolution of quantum statistics, exchange symmetry and exchange degeneracy.

Unit-III: Symmetry, invariance principle, and conservation *(9 L)*

Space and time translations, rotational invariance under infinitesimal and finite rotations. Angular momentum operators, ladder operators, addition of angular momenta - Clebsch-Gordan coefficients, Wigner-Eckart theorem, time evolution.

Unit-IV: Approximation methods in quantum mechanics *(14 L)*

Time independent perturbation theory, Stark and Zeeman effects, variational method and its applications, WKB approximation, time dependent perturbation theory, transition to continuum states, Fermi's Golden rule, adiabatic and sudden approximation

PRACTICAL [Credit: 01]

Full Marks: 25 **Internal Assessment: 5** **End Semester: 20**

Contents:

The students need to complete at least four experiments from the given set of seven practicals

1. To set up the Millikan's oil drop apparatus and determine the charge of an electron.
2. To determine the wavelength of H-alpha emission line of Hydrogen atom.
3. To determine the value of e/m by a) magnetic focusing or b) bar magnet.
4. Verify Heisenberg's uncertainty principle using He-Ne laser.
5. Draw the V-I characteristic curve of a tunnel diode.
6. Draw the V-I characteristic curve of a Gunn diode.
7. Determine the value of the Planck Constant using LED.

Reference Books:

1. Quantum Mechanics, L I Schiff
2. Quantum Mechanics, S N Biswas
3. Quantum Mechanics, A K Ghatak and S Lokanathan
4. Introductory Quantum Mechanics, R L Liboff
5. Principles of Quantum Mechanics, R Shankar
6. Quantum Mechanics: concepts and applications, N Zettili
7. Introduction to Quantum Mechanics, David J Griffiths

Two Year Post Graduate Programme in Physics
Semester -I
Paper Name: Electronics
Paper Code: PHY-CC-201034
Total number of lectures: 45 L
Total credits: 4 (Theory 3 + Pract 1)
Total Marks: (45 (Th) + 25 (Pract) + 30 (Int))

Course Outcomes:

CO1: Recall the basic principle of electronics.
CO2: Explain the working of different electronic circuits and components.
CO3: Operate on the various electronic circuits and components.
CO4: Relate different components of electronic systems.
CO5: Summarize the use of electronic circuits for various applications.

Contents:

Unit-I: Electronic Devices and applications (9 L)

Carrier concentrations in semiconductors; direct and indirect band gap semiconductors, Band structure of p-n junction; Homo and hetero-junction devices; SCR. UJT. JFET. MOSFET. CMOS. Tunnel diode. GUNN diode.

Application of UJT: Relaxation oscillator, Application of SCR**:** Saw tooth generator. Application of JFET: Amplifier, AC equivalent circuit, and voltage gain. Application of CMOS: as NOR gate and NAND gate operation.

Unit-II: Optoelectronics (7 L)

Working principle of LED. Relation between forbidden energy gap and emitted wavelength. Power and quantum efficiency of LED.

Photodetector materials. The basic principle for optical detection. P-N junction photodiode and its disadvantage. Noise in optical devices. . Photo Transistor, its structure, and operation.

Unit-III: Filters (6 L)

Ideal filters, Low pass. High Pass, Band pass and band reject filters. Cut off frequency and roll-off rate for different orders, Use of OPAMP as filters, Design of 1^{st} order Low Pass, High Pass, Band Pass, and Band Reject filter.

Unit-IV: Data Processing Circuits (5 L)

The basic idea of Multiplexers. De-multiplexers. Decoders. Encoders.

Unit-V: Counters (4 bits) (3 L)

Ring Counter. Asynchronous counters. Decade Counter. Synchronous Counter.

Unit-VI: Conversion of Analog and Digital Voltages (3 L)

Digital to analog conversion (DAC): Resistive network (Weighted and R – 2R Ladder). Analog to digital conversion (ADC): Basic block diagram. Nyquist Rate. Counter type ADC. Successive approximation method. Accuracy and Resolution of ADC.

Unit-VII: Intel 8085 Microprocessor Architecture (4 L)

Microprocessor as a CPU, organization of Microprocessor based systems, 8085 Architecture, operations and pin diagram, 8085 programming model: Registers, Flags, Program counter and Stack pointer, Bus organization, Microprocessor communication and Bus Timing, Stack and Subroutine. Introduction to Assembly language (basic concept)

Unit-VIII: Introduction to Communication System (5 L)

Introduction to analog and digital communication. Amplitude and Frequency Modulation, modulation index, bandwidth and frequency spectrum (Basic Concept), Advantage and Disadvantage of Analog and Digital Communication. Representation of Digital Communication using ASK, FSK, PSK (Basic Concept)

Unit IX: Nanoelectronics (3 L)

Introduction to nanoelectronics (basic concept, Introduction to nanolithography process with an overview of photolithography (Basic Concept).

PRACTICAL [Credit: 01]

Full Marks: 25 **Internal Assessment: 5** **End Semester: 20**

Contents:

The students need to complete at least four experiments from the given set of seven practicals

1. Study OPAMP as an amplifier and RC phase shift oscillator. Draw the transfer characteristics of the amplifier in different feedback configurations. Estimate the practical and theoretical frequency of oscillation.
2. Design an integrator and differentiator circuit using 741 IC. Draw the frequency response and observe the output for different inputs.
3. Measure the resistivity and hence the band gap of a semiconductor using four-probe method.
4. Design and study the gain of an Instrumentation Amplifier.

5. To build a 4-bit Counter using D-type/JK Flip-Flop ICs and study timing diagram.
6. Design high pass filter using OPAMPs. Estimate the cutoff frequency and roll-off rate.
7. Design low pass filter using OPAMPs. Estimate the cutoff frequency and roll-off rate.

Reference Books:

1. Electronic Devices and Circuit Theory, R L Boylestad
2. Electronic Devices and Circuits, T Bogart, J S Beasley and G Rico
3. Electronic Devices, T L Floyd
4. Modern Digital Electronics, R P Jain
5. Optoelectronics and Fiber Optics Communication, C K Sarkar and D C Sarkar
6. OPAMPS and Linear Integrated Circuits, Ramakant A Gayakwad.
7. Operational Amplifier and Linear Integrated Circuits, R F Coughlin and F F Driscoll.
8. Modern Digital and Analog Communication Systems, B P Lathi.
9. Electronic Communication System, George Kennedy. 6. Communication Systems, Simon Haykin
10. Microprocessor Architecture Programming & applications with 8085, 2002, R. S. Goankar, Prentice Hall.

Two Year Post Graduate Programme in Physics

Semester -I

Paper Name: Research Methodology
Paper Code: PHY-CC-201044
Total number of lectures: 60 (45 L + 15 T)
Total credits: 4 (Theory 3 +Tutorial 1)
Total Marks: 100 (60 (Th)+40 (Int))

Course Outcomes:

CO 1: Develop a research plan, and formulate the objectives
CO 2: Use internet, and carry out a survey of literature
CO 3: Examine data by statistical approach
CO 4: Present the findings as a research paper, or a powerpoint/poster presentation
CO 5: Infer on plagiarism

Contents:

Unit-I: Introduction to Research. (15 L + 5 T)

Research: meaning, characteristics and types. Paper, article, workshop, seminar, conference and symposium; Defining each major concept in operational terms: an overall description of approach, clearly stating any assumptions; Details of techniques. Expected outcome. Methodology to be adopted, planning of experiments for achieving the aims and objectives. Reproducibility of research work. Literature survey of the previous works. Review of an article in the relevant field and preparation of a short report. Use of internet networks in research activities in searching material, paper downloading. Sources, acquisition and interpretation of data. Quantitative and qualitative data. Graphical representation and mapping of data.

Unit-II: Statistical analysis (15 L + 5 T)

Error analysis and propagation. Types of data, Representation of data: tabular and diagrammatic methods, Inference from data: averages and higher moments. Scatter plots: Correlation tests. Conditional probability, Bayes theorem, probability distributions, likelihood estimation. Data-fitting (regression), types of errors, hypothesis testing and confidence limits.

Unit-III: Research Presentation and Academic Integrity (15 L + 5 T)

Steps of scientific writing: flow method, organisation of material and style. Types of report: research paper, thesis/dissertation. Drawing figures, graphs, tables, footnotes, references etc. in a research paper. Preparation in power point for oral, and for poster presentation in scientific seminar. Development of communication skill in presentation of scientific seminars: eye to eye contact, facing to audience, question & answer sessions etc. Plagiarism: meaning, why and how to avoid it, self-plagiarism.

Suggested Books:

1. Research Methodology: Methods and Techniques, by C.R. Kothari and Gaurav Garg, New Age International Publishers.
2. Research Methodology and Techniques in Physics, by Anil Kumar Singh, Anmol Publishers.
3. Research Methods: The Basics, by Nicholas Walliman, Taylor and Francis.
4. Data Reduction and Error Analysis for Physical Sciences, by Philip R. Bevington and D. Keith Robinson, McGraw-Hill Education.
5. The Ethics of Teaching and Scientific Research, Edited by Sidney Hook, Paul Kurtz and Miro Todorovich, Prometheus Books, 1977.

Two Year Post Graduate Programme in Physics

Semester -I

Paper Name: Computational and Scientific Programming with Python

Paper Code: PHY-EC-201054
Total number of lectures: 45 L
Total credits: 4 (Theory 3 +Practical 1)
Total Marks: 100 (45 (Th) + 25 (Pract) + 30 (Int))

Course outcomes:

- Explain the fundamentals of Python programming, configure scientific computing environments, an d develop basic Python programs using variables, data types, operators, input/output operations, and string manipulation.
- Apply Python data structures, conditional statements, loops, functions, and modules to develop struc tured and reusable programs for solving computational problems.
- Utilise NumPy and SciPy libraries for numerical and scientific computing, including array manipulat ion, linear algebra, numerical integration, optimisation, interpolation, statistical analysis, and solving systems of equations.
- Apply random number generation and symbolic computation techniques using appropriate Python li braries to perform mathematical and scientific calculations.
- Create and customise scientific visualisations using Matplotlib and Seaborn, employing appropriate plots, labels, legends, annotations, colour maps, and export formats to present scientific data clearly and effectively.

Contents:

Unit 1: Scientific Computing Environment and Programming Foundations (10 L)

What is Python? Setting up Python environment (IDLE). Working with Colab, Jupyter Notebook and VS Code. Basic syntax and variables. Simple input/output operations. Numbers, strings, and boolean data types. Arithmetic, comparison, and logical operators. String manipulation. Floating-point representation, rounding error, and machine precision.

Unit II: Data Types, Control Flow and Functions and Modules (11 L)

Basic Data Types: Numeric, String, List, Tuple, Dictionary, Boolean, Sets. Conditional Statements: if, else and elif. Python Pass Statement. Ternary operator. Looping: while, for, Nested loops. Loop Control Statements: continue, break pass. Defining and calling functions, Parameters and return, Python modules.

Unit III: Numerical Computing with NumPy and SciPy (12 L)

NumPy arrays: creation, dtypes, shape, indexing, slicing, and boolean masking. Universal Functions, and broadcasting rules. Array manipulation (reshape, stack, split) and performance comparison with Python lists. Linear algebra with numpy. linalg: matrix products, determinant, inverse, eigenvalues and eigenvectors, SVD, and solving linear systems. Random number generation and sampling. Overview of SciPy sub-packages (constants, linalg, optimize, integrate, interpolate, stats, fft, special). Introduction to symbolic computation with SymPy.

Unit IV: Scientific Data Visualisation (12 L)

Matplotlib architecture: figure, axes, and the object-oriented interface. Line, scatter, bar, histogram, error-bar, contour, and 3D plots. Subplots, annotations, legends, logarithmic scales, and LaTeX-style labels. Customising styles and exporting publication-quality figures (PDF, PNG, SVG). Statistical plots with Seaborn. Principles of effective scientific visualisation (clarity, colour maps, accessibility).

PRACTICAL [Credit: 01]

Full Marks: 25 **Internal Assessment: 5** **End Semester: 20**

Contents:

The students need to complete at least six from the following

1. Write a program using functions to compute the area and circumference of a circle, with input validation and exception handling.
2. Compute the sum, mean, median, maximum, minimum, and range of a list of numbers; sort in ascending and descending order without built-in sort.
3. Generate even/odd numbers and primes between given limits using loops, comprehensions, and generators.
4. Find the roots of a quadratic equation (real, equal, and complex cases) and determine whether a year is a leap year.
5. Perform set operations (union, intersection, difference, symmetric difference) and dictionary-based word or element frequency counting.
6. Matrix operations using NumPy: product, determinant, inverse, eigenvalues and eigenvectors; compare speed with pure-Python loops.
7. Solve a system of linear equations by Gaussian elimination, and verify with numpy. Linalg.solve.
8. Read a CSV or text file with Pandas, clean the data, and compute a frequency distribution with mean, standard deviation, and skewness.
9. Least-squares curve fitting of experimental data with curve_fit; report fit parameters, uncertainties, and chi-square.
10. Generate publication-quality plots (error bars, subplots, log scale, histogram) from a data file using Matplotlib.

Suggested Readings:

1. Hill Christian (2020) Learning Scientific Programming with Python, Cambridge University Press.
2. Sastry S.S (2012) Introduction to Numerical Analysis, PHI Learning Pvt. Ltd.
3. Kanetkar Yashwant and Kanetkar Aditya (2023) Let us Python, BPB Publications
4. Gupta Abhijit K Scientific Computing in Python (2021) 2nd Edition, Techno World
5. Banerjee Abhinaba (2024) Python Libraries for Data Analysis and Visualization, Orange Education Pvt Ltd

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