



Department of Physics

Master of Science in Physics

Doon University

Based on NEP-2020

(Effective from academic session 2025-2026)

1. Introduction to Master of Science in Physics

The Master of Science in Physics is a four-semester course, spread over two academic years. The teaching-learning process is student-centric and it involves both theory and practical components. It offers a flexibility of programme structure while ensuring that the student gets a strong foundation in the subject

and gains in-depth knowledge. There is the combination of courses that include DSC (discipline specific core course) and DSE (discipline specific elective courses). Thereby, bringing out the multidisciplinary approach and adherence to innovative ways within the curriculum framework.

2. Program Outcomes:

Program	Program Outcomes
MSc in Physics	After studying Physics in M.Sc. Program students will be able to: PO1: In-depth disciplinary knowledge Acquire comprehensive knowledge and gain an understanding of the fundamental principles, theoretical principles and processes in the main and allied branches of Physics. The students would be able to have strong foundation knowledge and comprehend the basic concepts and principles in Physics. PO2: Problem-Solving To instill in the learners the spirit of inquiry and innovation. Sharpen analytical thinking, problem-solving prowess, and critical reasoning which are versatile skills applicable across a multitude of domains. Fostering collaboration and interdisciplinary approaches to problem-solving skills. PO3: Hands-on/ Laboratory Skills Comprehensive hands-on/ laboratory exercises will impart analytical, computational and instrumentation skills. The students will be able to demonstrate mature skills for the collation, evaluation, analysis and presentation of information, ideas, concepts as well as quantitative and/or qualitative data. PO4: Building Research skills To instill in the learners the spirit of inquiry and innovation and inculcate research skills along with data analysis and research ethics. PO5: Channels for Knowledge Transfer To create opportunity platforms for nucleation and incubation of entrepreneurs and to build synergistic channels for productive knowledge transfer and utilization through industry partners. PO6: Career Opportunities through Networking To create value added linkages and career opportunities for faculty and students through effective networking both at national and international levels. To network with national and global academic institutions through vibrant exchange programmes and collaborations in teaching and research. PO7: Lifelong learning skills and Entrepreneurship Ability to learn lifelong learning skills which are important to provide better opportunities and improve quality of life. Capable to establish an independent startup/innovation center etc. Students can pursue further education or careers in physics, chemistry, materials science, engineering, education, computers science or related areas.

3. Program Specific Outcomes:

Program	Program Specific Outcomes
	The programme ensures that the learners PSO1: Acquire core competency in the areas of Basic and Applied Physics

MSc in Physics	PSO2: are exposed to the state-of-art facilities in the Department and collaborating institutions in the neighborhood PSO3: are familiarized with current trends in a wide variety of sub-disciplines and emerging areas of Physics are able to apply their acquired skills in other interdisciplinary areas of science and technology. PSO4: are equipped with knowledge to engage in teaching in academic institutions, research in National research laboratories and R&D based industries as also initiating technology-based entrepreneurship PSO5: gets accomplished in mathematical techniques such as calculus, differential equations, linear algebra, and vector calculus. PO6: develops hands-on skills in experimental design, analysis, and interpretation of results, enhancing their ability to apply theoretical concepts to practical situations. PO7: Develop a good understanding of semiconductor materials, device physics, and fabrication techniques, preparing them for careers in semiconductor and optoelectronics sector.
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4. Definitions and Abbreviations

- i. **Academic Credit:** An academic credit is a unit by which the course work is measured. It determines the number of hours of instructions required per week. One credit is equivalent to one hour of teaching (lecture or tutorial) or two hours of practical work/ three hours of any training per week.
- ii. **Courses of Study:** Courses of the study indicate pursuance of study in a particular discipline. Every discipline shall offer different categories of courses of study, viz. Discipline Specific Core (DSC) courses, Discipline Specific Electives (DSEs), Dissertation project etc.
- iii. **Discipline Specific Core (DSC):** Discipline Specific Core is a course of study, which should be pursued by a student as a mandatory requirement of his/ her programme of study. In Master of Science (Hons.) Physics programme, DSCs are the core credit courses of Physics which will be appropriately graded and arranged across the semesters of study, being undertaken by the student.
- iv. **Discipline Specific Elective (DSE):** The Discipline Specific Electives (DSEs) are a pool of credit courses of Physics from which a student will choose to study based on his/ her interest. A student of MSc Physics, gets an option of choosing one DSE of Physics in each of the semesters III to VI, while the student has an option of choosing a maximum of three DSE courses of Physics in semesters VII and VIII.
- v. **Generic Elective (GE):** Generic Electives is a pool of courses offered by various disciplines of study (excluding the GEs offered by the parent discipline) which is meant to provide multidisciplinary or interdisciplinary education to students. In case a student opts for DSEs beyond his/ her discipline specific course(s) of study, such DSEs shall be treated as GEs for that student.

5. Programme Duration and Exit Options

The minimum credits to be earned by the student per semester are 22 credits. This provision

is meant to provide students the comfort of the flexibility of semester-wise academic load and to learn at his/her own pace. However, the mandatory number of credits which needs to be secured for the purpose of award of postgraduate diploma/Appropriate Master's Degree in Physics are listed in Table 1.

Table 1: Award with credit requirement

S. No.	Name of Award	Stage of Exit	Mandatory
1	Postgraduate diploma in Physics	After successful completion of Semester II	44
2	Mater of Science in Physics	After successful completion of Semester IV	88

6. Attainment of Course outcome and Evaluation

A continuous evaluation will be carried out along with teaching, practical, assignments, quiz etc.

a. Teaching Methods

Theory + practical
Theory+ Tutorial
Theory+ Projects
Theory only
Project/Dissertation only
Practical only

b. The class assignments for different course segments are as follows

Theory	1 credit	1 hour/week
Practical	1 credit	2 hours/week
Tutorial	1 credit	1 hour/week
Projects	1 credit	1 hour/week

Evaluation Methods:

Class assignments, Quiz, Test, Class Interaction, Practical's, Projects, Attendance Midterm Examination, End term Examination

7. Programme and Frame Work

Semester	Discipline Specific Core Course (DSC)	Discipline Specific Elective (DSE)/ Generic Elective (GE)	Skill Enhancement Course (SEC)/ Project/ Dissertation	Value Addition Course (VAC)/ Ability Enhance ment Course (AEC)	Total Credits earned
1.	DSC1: Mathematical Physics	DSE1/GE1	Seminar/Project (2 Credits)	-	22
	DSC2: Classical Physics	DSE2/GE2			
	DSC3: Quantum Mechanics				
2.	DSC4: Electrodynamics	DSE3/GE3	Seminar/Project (2 Credits)	-	22
	DSC5: Condensed Matter Physics	DSE4/GE4			
	DSC6: Atomic and Molecular Physics				
3.	DSC7: Computational Physics	DSE5/GE5	Seminar/Project (2 Credits)	-	22
	DSC8: Statistical Mechanics	DSE6/GE6			
		DSE7/GE7			
	OR				
	(i) Seminar (2 Credits)				
(ii) Dissertation/Academic Project/Entrepreneurship (20 Credits)					
4.	DSC9: Energy Materials and Semiconductor Devices	DSE8/GE8	Seminar/Project (2 Credits)	-	22
		DSE9/GE9			
	DSC10: Advanced Condensed Matter Theory	DSE10/GE10			
	OR				
	(i) Seminar (2 Credits)				
(ii) Dissertation/Academic Project/Entrepreneurship (20 Credits)					

The detailed framework of undergraduate degree programme in Physics is provided in following Table 2.

Table 2: Semester-wise Course Frame Work

S. N	Course Code	Course Type	Name of the Course	L	T	P	Total Credits
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Semester I							
1	PHC501	DSC 1	Mathematical Physics	3	1	0	4
2	PHC502	DSC 2	Classical Physics	3	1	0	4
3	PHC503	DSC 3	Quantum Mechanics	3	1	0	4
4	PHE501	DSE1/GE1	choose from the pool of courses*	3	0	1	4
5	PHE502	DSE2/GE2	choose from the pool of courses*	0	0	4	4
6	PHP501	Seminar/Project		0	0	2	2
Total Credits 22							
Semester II							
1	PHC551	DSC 4	Electrodynamics	3	1	0	4
2	PHC552	DSC 5	Condensed Matter Physics	3	1	0	4
3	PHC553	DSC 6	Atomic and Molecular Physics	3	1	0	4
4	PHE503	DSE3/GE3	choose from the pool of courses*	3	1	0	4
5	PHE504	DSE4/GE4	choose from the pool of courses*	0	0	4	2
6	PHP551	Seminar/Project		0	0	2	2
Total Credits 22							
Exit option after one year with 44 credits with PG Diploma in Physics							
Semester III							
1	PHC601	DSC 7	Computational Physics	3	0	1	4
2	PHC602	DSC 8	Statistical Mechanics	3	0	1	4
3	PHE505	DSE5/GE5	choose from the pool of courses*	3	0	1	4
4	PHE506	DSE6/GE6	choose from the pool of courses*	3	1	0	4
5	PHE507	DSE7/GE7	choose from the pool of courses*	0	0	4	4
6	PHP601	Seminar/Project		0	0	2	2
OR							
1		Seminar		0	0	2	2
	PHD601	Dissertation/Academic Project/Entrepreneurship		20			
Total Credits 22							
Semester IV							
	PHS651	Seminar		0	0	2	2

1	PHD651	Dissertation/Academic Project/Entrepreneurship		20			
OR							
1	PHC651	DSC 9	Energy Materials and Semiconductor Devices	3	1	0	4
2	PHC652	DSC 10	Advanced Condensed Matter Theory	3	1	0	4
3	PHE508	DSE8/GE8	choose from the pool of courses*	3	0	1	4
4	PHE509	DSE9/GE9	choose from the pool of courses*	3	1	0	4
5	PHE510	DSE10/GE10	choose from the pool of courses*	3	1	0	2
6	PHP651	Seminar/Project		0	0	2	2
Total Credits 22							
After Two years with 88 credits the student will be awarded the degree of MSc in Physics							

DISCIPLINE SPECIFIC COURSES

SEMESTER-I

PHC501: Mathematical Physics

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objective:

1. To enable students, learn essential mathematical tools for solving physics problems at masters' level.
2. To enable to solve problems in complex analysis, vector spaces.
3. To understand the concepts of Fourier and Laplace transform.

After completion of this course, students will be able to:

S No.	Course Outcome Statement	Bloom's Level(s)
CO1	Students will be able to learn basics of Complex Analysis, Vector spaces, matrices, Integral transforms, ordinary differential equations and special functions.	B1, B2 (<i>Remember, Understand</i>)
CO2	After this course students are capable to use the applications of these methods in basic physics problems	B3, B4 (<i>Apply, Analyze</i>)
CO3	Explain the concepts of differential equations and special functions.	B2, B4 (<i>Understand, Analyze</i>)

CO-PO Mapping Matrix of Classical Mechanics

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	✓		✓				✓
CO2	✓	✓	✓				✓
CO3	✓	✓		✓			✓

Course Content:

UNIT 1

Linear vector spaces

Linear vector space, dual vector space, inner product spaces. Linear (in)dependence, bases, dimension. Linear operators, matrices for linear operators. Eigenvalues and eigenvectors. Similarity transformation, (matrix) diagonalization, Gram-Schmidt algorithm. Special matrices: normal, Hermitian and unitary matrices. Cauchy-Schwarz and triangle inequalities.

(13 lectures)

UNIT 2

Complex analysis

Review of complex analyticity, branch points and branch cuts and line integrals and related theorems and consequences. Taylor and Laurent expansions and residues. Evaluation of definite integrals. Fourier Series, Fourier and Laplace Transforms.

(15 lectures)

UNIT 3

Ordinary Differential Equations and Special Functions

Linear ordinary differential equations, singular points and their classification. Linear independence and Wronskian. Series solution, second solution.

Special functions: Bessel functions and classical polynomials (Legendre, Hermite and Laguerre). Gamma function, zeta function.

(20 lectures)

UNIT 4

Partial Differential Equations

Laplace and Poisson equation (with particular emphasis on solving boundary value problems). Wave equation. Heat Equation. Separation of variables and solution in different coordinates. Green's function approach.

(12 lectures)

Reference Books:

- K. F. Riley, M. P. Hobson and S. J. Bence, Mathematical Methods for Physics and Engineering, Cambridge.
- G.B. Arfken, Mathematical Methods for Physicists, Elsevier
- P. Dennery and A. Krzywicki, Mathematics for Physicists, Dover.

- S.D. Joglekar, Mathematical Physics: Basics (Vol. I) and Advanced (Vol. II), Universities Press
- V. Balakrishnan, Mathematical Physics, Ane Books
- A.W. Joshi, Matrices and Tensors in Physics, New Age Publishers
- M.R. Spiegel, Complex Variables, McGraw-Hill
- R.V. Churchill and J.W. Brown, Complex Variables and Applications, McGraw-Hill
- P.M. Morse and H. Feshbach, Methods of Theoretical Physics (Vol. I & II), Feshbach Publishing
- Seymour Lipschutz, Schaum's outline of theory and problems of beginning linear algebra, McGraw-Hill Education

Lecture plan- Mathematical Physics (60 lectures)

UNIT 1: Linear Vector Spaces (13 Lectures)

- Lecture 1:** Introduction to linear vector spaces: definitions, examples from physics.
Lecture 2: Dual vector space and linear functionals.
Lecture 3: Inner product spaces, norms, orthogonality.
Lecture 4: Linear independence and dependence, spanning sets, bases and dimension.
Lecture 5: Linear operators and their matrix representation.
Lecture 6: Eigenvalues, eigenvectors, and characteristic equations.
Lecture 7: Diagonalization of matrices and similarity transformations.
Lecture 8: Gram-Schmidt orthogonalization procedure.
Lecture 9: Special matrices: Hermitian, unitary, normal matrices and their properties.
Lecture 10: Properties of eigenvalues for Hermitian and unitary matrices.
Lecture 11: Cauchy-Schwarz inequality and triangle inequality with physical examples.
Lecture 12: Applications of vector space concepts in quantum mechanics (Dirac notation).
Lecture 13: Problem-solving session on eigenvalue problems and matrix diagonalization.

UNIT 2: Complex Analysis (15 Lectures)

- Lecture 1:** Review of complex variables: analyticity and Cauchy-Riemann equations.
Lecture 2: Complex integration, line integrals and contour integration basics.
Lecture 3: Singularities: poles, branch points and branch cuts.
Lecture 4: Cauchy's theorem and Cauchy's integral formula.
Lecture 5: Taylor and Laurent series expansions.
Lecture 6: Residue theorem and evaluation of simple integrals.
Lecture 7: Residue theorem applications: semi-circular contours and improper integrals.
Lecture 8: Branch cut integrals and multi-valued functions.
Lecture 9: Fourier series: convergence criteria and basic properties.
Lecture 10: Complex form of Fourier series and Parseval's theorem.
Lecture 11: Fourier transforms: definition, properties, examples.
Lecture 12: Laplace transforms: definition and properties.
Lecture 13: Applications of Fourier and Laplace transforms in solving physics problems.
Lecture 14: Problem-solving session on residues and transforms.
Lecture 15: Comprehensive practice session (complex analysis + transforms).

UNIT 3: Ordinary Differential Equations and Special Functions (20 Lectures)

- Lecture 1:** Review of ordinary differential equations: first and second order linear ODEs.
Lecture 2: Singular points of ODEs and classification.

Lecture 3: Series solution near regular points.
Lecture 4: Frobenius method for regular singular points.
Lecture 5: Second linearly independent solution using Wronskian.
Lecture 6: Bessel's equation: solution and properties of Bessel functions.
Lecture 7: Applications of Bessel functions in physics (waveguides, vibrations).
Lecture 8: Legendre differential equation: solution and Legendre polynomials.
Lecture 9: Properties and orthogonality of Legendre polynomials.
Lecture 10: Hermite polynomials: solution of Hermite's equation and properties.
Lecture 11: Laguerre polynomials: solution and orthogonality.
Lecture 12: Applications of special functions in quantum mechanics and electromagnetism.
Lecture 13: Gamma function: definition and properties.
Lecture 14: Beta function and relation to Gamma function.
Lecture 15: Riemann zeta function: definition and basic properties.
Lecture 16: Advanced properties of special functions (recurrence relations).
Lecture 17: Problem-solving session on special functions.
Lecture 18: Comprehensive review: special functions and series solutions.
Lecture 19: Numerical illustrations and computational approaches.
Lecture 20: Introduction to PDEs and classification (elliptic, hyperbolic, parabolic).

UNIT 4: Partial Differential Equations (12 Lectures)

Lecture 1: Introduction to PDEs and classification (elliptic, hyperbolic, parabolic).
Lecture 2: Laplace's equation and boundary value problems.
Lecture 3: Poisson's equation and applications in electrostatics.
Lecture 4: Wave equation: separation of variables method.
Lecture 5: Heat equation: separation of variables method.
Lecture 6: Solutions in Cartesian coordinates.
Lecture 7: Solutions in cylindrical and spherical coordinates.
Lecture 8: Green's function: definition and properties.
Lecture 9: Green's function approach to solving Poisson's and Laplace's equations.
Lecture 10: Physical applications of Green's function (electrostatics, quantum mechanics).
Lecture 11: Practice session on PDEs and boundary value problems.
Lecture 12: Advanced PDE applications and mixed boundary conditions.

PHC502: Classical Mechanics

Total Credits: 04 (Credits: Theory:03, Tutorial:01)

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objectives:

- 1.To develop the idea of theoretical understanding of motion of a group of particles involving a wide range of length and energy scales.
- 2.To develop an understanding of Lagrangian and Hamiltonian formulation and their applications which allow for simplified treatments of many complex problems in classical mechanics and provides the foundation for the modern understanding of dynamics.

Course Outcome:

S. No.	Course Outcome Statement	Bloom's Level(s)
CO1	To understand the Lagrangian approach in classical mechanics	B2, B3, B4 (Understand, Apply, Analyze)
CO2	Learn to finding solution of a time evolution of state of a system employing Lagrangian and Hamiltonian approaches.	B1, B3, B4, B5 (Remember, Apply, Analyze, Evaluate)
CO3	To understand Hamiltonian formulation with applications	B2, B3, B4 (Understand, Apply, Analyze)
CO4	To understand the two-body central force problem and small oscillations problem in detail considering the direct applications in many systems at atomic to stellar scale.	B2, B3 (Understand, Apply)
CO5	To understand the concept of free oscillations, analyze free and forced vibrations using normal coordinates.	B2, B3, B4 (Understand, Apply, Analyze)
CO6	To learn about relativistic system.	B1, B3, B4 (Remember, Apply, Analyze)

CO-PO Mapping Matrix of Classical Mechanics

CO/ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	✓	✓					✓
CO2	✓	✓		✓			
CO3	✓	✓		✓			
CO4	✓	✓		✓			

CO/ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO5	✓	✓		✓			
CO6	✓	✓				✓	✓

Course Content:

UNIT 1

Lagrangian and Hamiltonian Formulations of Mechanics: Constraint, Degree of freedom, generalized coordinates, Virtual displacement, Principle of virtual work, D'Alembert Principle, Theorem of total energy, Cyclic coordinates, Generalized momenta, Hamilton's principle of least action, Lagrange's equations of motion, conservation laws, systems with a single degree of freedom, rigid body dynamics, Hamilton's equations of motion, phase plots, Jacobi integral, Lagrangian and Hamiltonian of relativistic particles, Problem solving.

(16 Lectures)

UNIT 2

Hamiltonian Mechanics and Chaos: Variation principle, Background and definition of Poisson brackets, Jacobi identity, Legendre transformation, Generating function, Condition for canonical transformations, Invariance of Poisson bracket under canonical transformation, Hamilton- Jacobi theory, action-angle variables, perturbation theory, integrable systems, introduction to chaotic dynamics. Problem solving.

(10 Lectures)

UNIT 3

Two-Body Central Force Problem: Equation of motion and first integrals, differential equation of the orbit, classification of orbits, Kepler problem, scattering in central force field.

(8 Lectures)

UNIT 4

Small Oscillations: Oscillations about equilibrium, Linearization of equations of motion, free vibrations and normal coordinates, forced oscillations. Problem solving.

(6 Lectures)

UNIT 5

Special Theory of Relativity: Lorentz transformation, relativistic kinematics and dynamics, Equation of energy in relativistic mechanics; mass energy relation. Problem solving.

(5 Lectures)

Reference Books:

1. H. Goldstein, Classical Mechanics.

2. J.C Upadhyaya, Himalaya Publishing House, Classical Mechanics.
3. L.D. Landau and E.M. Lifshitz, Mechanics.
4. I.C. Percival and D. Richards, Introduction to Dynamics.
5. J.V. Jose and E.J. Saletan, Classical Dynamics: A Contemporary Approach.
6. E.T. Whittaker, A Treatise on the Analytical Dynamics of Particles and Rigid Bodies.
7. N.C. Rana and P.S. Joag, Classical Mechanics.

Lecture Plan- Classical Mechanics (45 Lectures)

UNIT 1: Lagrangian and Hamiltonian Formulations of Mechanics (16 Lectures)

- Lecture 1:** Calculus of variations and principle of least action.
- Lecture 2:** Phase space, phase plots, and energy surfaces.
- Lecture 3:** Constraints and Degrees of Freedom
- Lecture 4:** Euler-Lagrange equations and generalized coordinates.
- Lecture 5:** Principle of virtual work and D'Alembert Principle.
- Lecture 6:** Cyclic coordinates and generalized momenta
- Lecture 7:** Lagrange's equations of motion for a system.
- Lecture 8:** Conservation Laws in Lagrangian Mechanics
- Lecture 9:** Analyze conservation laws using cyclic coordinates and generalized momenta.
- Lecture 10:** Applications of Lagrange's Equations for single DOF system
- Lecture 11:** Systems with single degree of freedom and rigid body dynamics.
- Lecture 12:** Hamilton's principle and derivation of Hamilton's equations.
- Lecture 13:** Hamiltonian formulation and canonical equations.
- Lecture 14:** Jacobi Integral and Its Significance
- Lecture 15:** Lagrangian and Hamiltonian for Relativistic Particles
- Lecture 16:** Problem-solving session and practice problems.

UNIT 2: Hamiltonian Mechanics and Chaos (10 Lectures)

- Lecture 1:** Hamilton's Principle and Variational Formulation.
- Lecture 2:** Poisson brackets and their properties.
- Lecture 3:** Jacobi Identity and applications to conserved quantity.
- Lecture 4:** Legendre Transformation.
- Lecture 5:** Canonical Transformations and Generating Functions.
- Lecture 6:** Poisson brackets and Invariance of Poisson Brackets
- Lecture 7:** Hamilton-Jacobi Theory
- Lecture 8:** Action-Angle Variables and Perturbation Theory
- Lecture 9:** Integrable Systems and Introduction to Chaos
- Lecture 10:** Problem-solving session and practice problems.

UNIT 3: Two-Body Central Force Problem (8 Lectures)

- Lecture 1:** Reduction to one-body problem in central force field.
- Lecture 2:** Equation of motion and first integrals.
- Lecture 3:** Classification of orbits: bound and unbound.
- Lecture 4:** Circular and elliptical orbit conditions.
- Lecture 5:** The Kepler problem: planetary motion.
- Lecture 6:** Scattering in central force field.
- Lecture 7:** Applications in atomic and astrophysical systems.
- Lecture 8:** Numerical and graphical problem solving.

UNIT 4: Small Oscillations (6 Lectures)

Lecture 1: Linearization of equations of motion near equilibrium.

Lecture 2: Normal coordinates and their significance.

Lecture 3: Examples of coupled oscillations.

Lecture 4: Free and forced oscillations.

Lecture 5: Resonance phenomena.

Lecture 6: Practice problems and physical interpretations.

UNIT 5: Special Theory of Relativity (5 Lectures)

Lecture 1: Lorentz transformation and its derivation.

Lecture 2: Length contraction and time dilation.

Lecture 3: Velocity addition and simultaneity.

Lecture 4: Relativistic dynamics and momentum.

Lecture 5: Mass-energy equivalence.

PHC503: Quantum Mechanics

Total Credits: 04 (Credits: Theory:03, Tutorial:01)

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objectives:

1. To provide a strong foundation in the fundamental principles of quantum mechanics.
2. To develop proficiency in the mathematical framework of quantum mechanics.
3. To familiarize students with the use of Dirac notation and formal quantum mechanical tools.
4. To introduce perturbation techniques in quantum mechanics.
5. To explore quantum mechanical phenomena within the context of special relativity.

Course Outcome:

S.No.	Course Outcome Statement	Bloom's Level(s)
CO1	Explain the foundational concepts of quantum mechanics and extend them to more advanced physical applications.	B2, B3 (Understand, Apply)
CO2	Formulate and solve problems using the mathematical structures of quantum mechanics, including operator algebra and Hilbert space.	B3, B4 (Apply, Analyze)
CO3	Apply the formalism and Dirac notation to describe and analyze non-relativistic quantum systems.	B3, B4 (Apply, Analyze)
CO4	Implement time-dependent and time independent perturbation theory to analyze transitions and interactions in quantum systems	B3, B4 (Apply, Analyze)
CO5	Describe and apply the principles of quantum scattering theory to compute scattering cross-sections and amplitude.	B2, B3 (Understand, Apply)
CO6	Apply Klein-Gordon and Dirac equations to analyze spin- $\frac{1}{2}$ particles, electromagnetic interactions, and relativistic effects like electron spin and antiparticles.	B3, B4 (Apply, Analyze)
CO7	Develop problem-solving skills and use appropriate mathematical tools for modeling advanced quantum phenomena.	B3, B5, B6 (Apply, Evaluate, Create)

CO-PO Mapping Matrix of Functional Topics of Physics

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	✓	✓		✓		✓	✓
CO2	✓	✓	✓	✓			✓
CO3	✓	✓	✓	✓			✓
CO4	✓	✓	✓	✓			✓
CO5	✓	✓	✓	✓			✓

CO6	✓	✓		✓		✓	✓
CO7	✓	✓	✓	✓			✓

Course Content:

UNIT 1

Non- Relativistic Quantum Mechanics and Operator formulation:

A brief review of foundations of quantum mechanics, basic postulates of quantum mechanics, Ehrenfest theorem. Vector representation of states, transformation of Hamiltonian with unitary matrix, Hilbert space. Dirac bra and ket notation, Various applications of Schrödinger equation (brief idea), Heisenberg and interaction pictures. Relationship between Poisson brackets and commutation relations, ladder operators and their matrix representation.

(6 Lectures)

UNIT 2

Spin and identical particles:

Concept of spin, Pauli spin matrices. Clebsch-Gordon coefficients and their properties, recursion relations. Schrödinger equation for a system consisting of identical particles, symmetric and anti-symmetric wave functions, elementary theory of the ground state of two electron atoms; ortho-and Para-helium. Scattering of identical particles.

(9 Lectures)

UNIT 3

Time independent Perturbation Theory:

Time independent perturbation theory for non- degenerate and degenerate systems upto second order perturbation. Application to a harmonic oscillator, first order Stark effect in hydrogen atom. Variation principle, application to ground state of helium atom, electron interaction energy and extension of variational principle to excited states. WKB approximation: energy levels of a potential well, quantization rules.

(9 Lectures)

UNIT 4

Time Dependent Perturbation Theory:

Time dependent perturbation theory, constant perturbation, Fermi Golden rule, coulomb excitation, sudden and adiabatic approximation, Harmonic perturbation, radiative transition in atoms, Semi-classical treatment of radiation.

(5 Lectures)

UNIT 5

Scattering Theory:

General considerations; kinematics, wave mechanical picture, scattering amplitude, differential and total cross-section. Green's function for scattering. Partial wave analysis: asymptotic behavior of partial waves, phase shifts, scattering amplitude in terms of phase shifts, cross-sections, optical theorem, phase shifts and its relation to potential, application to low energy scattering, exactly soluble problems; square-well, hard sphere, coulomb potential, Born approximation; its validity, Born series.

(9 Lectures)

UNIT 6

Relativistic Wave Equations:

Generalization of the Schrödinger equation; Klein-Gordon equation and its drawbacks, plane wave solutions, charge and current densities, interaction with electromagnetic fields, Dirac's equation for a free particle, relativistic Hamiltonian, probability density, expectation values, Dirac gamma matrices, and their properties, non-relativistic limit of Dirac equation, plane wave solution, energy spectrum of hydrogen atom, electron spin and magnetic moment, Non conservation of orbital angular momentum and idea of spin, interpretation of negative energy and theory of positron.

(7 Lectures)

Reference Books:

1. D. J. Griffiths, Introduction to Quantum Mechanics (Pearson).
2. J. J. Sakurai, Advanced Quantum Mechanics (Wesley).
3. N. Zettili, Quantum Mechanics Concepts and Applications (Wiley)
4. K. Ghatak and S. Lokanathan, Quantum Mechanics 3rd ed. (MacMillan).
5. L. I. Schiff, Quantum Mechanics (McGraw Hill).
6. C. Cohen-Tannoudji, Quantum Mechanics (Volume I and II).

Lecture Plan- Quantum Mechanics (45 Lectures)

UNIT 1: Non-Relativistic Quantum Mechanics and Operator Formulation (6 Lectures)

Lecture1: Review of quantum mechanics foundations & basic postulates

Lecture 2: Ehrenfest theorem; Vector representation of states

Lecture 3: Hilbert space and unitary transformation of Hamiltonian

Lecture 4: Dirac notation: bra-ket formalis

Lecture 5: Applications of Schrödinger equation; Heisenberg and interaction pictures

Lecture 6: Poisson brackets vs commutators; Ladder operators and matrix form

UNIT 2: Spin and Identical Particles (9 Lectures)

Lecture1: Concept of spin and Pauli spin matrices

Lecture2: Properties and algebra of Pauli matrices

Lecture3: Clebsch-Gordon coefficients and recursion relations

Lecture4: Schrödinger equation for identical particles

Lecture5: Symmetric and anti-symmetric wave functions

Lecture6: Ground state theory of two-electron atoms

Lecture7: Ortho- and Para-helium

Lecture8: Scattering of identical particles

Lecture9: Recap and problem-solving session

UNIT 3: Time-Independent Perturbation Theory (9 Lectures)

- Lecture2:** Degenerate perturbation theory
- Lecture3:** Application to harmonic oscillator
- Lecture4:** Stark effect in hydrogen (first order)
- Lecture5:** Variational principle: concept
- Lecture6:** Helium atom ground state using variational method
- Lecture7:** Electron interaction energy
- Lecture8:** Extension to excited states
- Lecture9:** WKB approximation & quantization rules

UNIT 4: Time-Dependent Perturbation Theory (5 Lectures)

- Lecture1:** Intro to time-dependent perturbation theory
- Lecture2:** Constant perturbation; Fermi Golden Rule
- Lecture3:** Coulomb excitation; sudden & adiabatic approximation
- Lecture4:** Harmonic perturbation & radiative transitions
- Lecture5:** Semi-classical treatment of radiation

UNIT 5: Scattering Theory (9 Lectures)

- Lecture1:** General concepts, kinematics, wave mechanical picture
- Lecture2:** Scattering amplitude; differential & total cross-section
- Lecture3:** Green's function for scattering
- Lecture4:** Partial wave analysis & asymptotic behaviour
- Lecture5:** Phase shifts and scattering amplitude
- Lecture6:** Cross-section, optical theorem
- Lecture7:** Phase shift vs potential; low energy scattering
- Lecture8:** Solvable problems: square well, hard sphere
- Lecture9:** Coulomb potential, Born approximation & Born series

UNIT 6: Relativistic Wave Equations (7 Lectures)

- Lecture1:** Generalization of Schrödinger equation; Klein-Gordon equation
- Lecture2:** Plane wave solutions, charge & current densities
- Lecture3:** Dirac equation for free particle; Dirac matrices
- Lecture4:** Relativistic Hamiltonian; probability density & expectations
- Lecture5:** Non-relativistic limit of Dirac equation; plane wave solutions
- Lecture6:** Hydrogen atom energy spectrum; spin & magnetic moment
- Lecture7:** Negative energy states & positron theory

PHE501: Electronics

Total Credits: 04 (Credits: Theory:03, Tutorial:01)

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objectives:

1. The course aims to develop a strong foundation in semiconductors, analog & digital electronics, signal processing, and high-frequency systems, equipping students with essential theoretical and practical skills.

2. Understand the fundamentals of Semiconductor Devices – Develop a deep understanding of diodes, transistors, field-effect devices, and optoelectronic components like LEDs and solar cells, along with their structural properties and applications.
3. Gain Proficiency in Analog Electronics – Learn the working and applications of operational amplifiers (Op-Amps), impedance matching, amplification techniques, and signal conditioning methods essential for circuit design.
4. To understand logic circuits, registers, counters, comparators, A/D and D/A conversion, and microprocessor basics for digital system applications.
5. Analyze High-Frequency Devices and Their Applications – Explore high-frequency generators and detectors, understanding their role in advanced communication and instrumentation systems.

Course Outcome:

S No.	Course Outcome Statement	Bloom's Level(s)
CO1	Explore semiconductor devices, including diodes, transistors, field-effect devices, and optoelectronic components like LEDs and solar cells.	B2(Understand)
CO2	Gain proficiency in analog electronics, covering operational amplifiers (Op-Amps), signal conditioning, impedance matching, and feedback circuits.	B3(Apply)
CO3	Develop expertise in digital electronics, including logic circuits, registers, counters, microprocessors, and A/D & D/A conversion techniques.	B3(Apply)
CO4	Analyze signal processing and communication techniques such as filtering, noise reduction, shielding, Fourier transforms, and modulation and explore high-frequency devices.	B4(Analyze)

CO-PO Mapping Matrix of PHE501: Electronics and Devices

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	✓	✓				
CO2	✓	✓		✓		
CO3	✓	✓	✓	✓		✓
CO4	✓	✓	✓	✓	✓	✓
CO5	✓	✓		✓	✓	
CO6	✓	✓				✓

Course Content:

UNIT 1

SEMICONDUCTOR DEVICES: Diodes, junctions, transistors, field-effect devices, homo- and hetero-junction devices, device structure, characteristics, frequency dependence, and applications. Opto-electronic devices including solar cells, photo-detectors, and LEDs. **(12 Lectures)**

UNIT 2

ANALOG ELECTRONICS: Operational amplifiers (Op-Amps) and their applications, impedance matching, amplification using Op-Amps and instrumentation amplifiers, feedback circuits, and signal conditioning and recovery. **(12 Lectures)**

UNIT 3

DIGITAL ELECTRONICS: Logic circuits, registers, counters, comparators, A/D and D/A converters, and microprocessor and microcontroller basics. **(10 Lectures)**

UNIT 4

SIGNAL PROCESSING, COMMUNICATION & HIGH-FREQUENCY DEVICES: Filtering and noise reduction, shielding and grounding, Fourier transforms, modulation techniques, and high-frequency devices including generators and detectors. **(16 Lectures)**

Reference Books:

- Millman's Integrated Electronics – Jacob Millman & Christos C. Halkias (McGraw-Hill)
- Electronic Devices and Circuit Theory – Robert L. Boylestad & Louis Nashelsky (Pearson)
- Op-Amps and Linear Integrated Circuits – Ramakant A. Gayakwad (Pearson)
- Digital Design: Principles and Practices – John F. Wakerly (Pearson)
- Microelectronic Circuits – Adel S. Sedra & Kenneth C. Smith (Oxford University Press)
- Signals and Systems – Alan V. Oppenheim, Alan S. Willsky (Pearson)
- Electronic Communication Systems – George Kennedy & Bernard Davis (McGraw-Hill)
- Microprocessor Architecture, Programming, and Applications with the 8085 – Ramesh S. Gaonkar (Penram International)

Lecture Plan- Electronics (45 Lectures)

UNIT 1: Semiconductor Devices (10 Lectures)

Lecture 1: Overview of semiconductor materials and intrinsic/extrinsic semiconductors.

Lecture 2: P-N junction diode: formation, characteristics, and dynamic resistance.

Lecture 3: Junction breakdown, Zener diode, and voltage regulation.

Lecture 4: Bipolar junction transistor (BJT): n-p-n and p-n-p configuration.

Lecture 5: Transistor characteristics in CE, CB, and CC modes.

Lecture 6: Field-effect transistor (FET): JFET, MOSFET – construction and working.

Lecture 7: Frequency response of BJT and FET devices.

Lecture 8: Hetero-junction and optoelectronic devices: LEDs and photodetectors.

Lecture 9: Solar cells: construction, characteristics, and efficiency.

Lecture 10: Summary and real-world device applications.

UNIT 2: Analog Electronics (10 Lectures)

- Lecture 1:** Introduction to operational amplifiers – ideal vs. practical characteristics.
 - Lecture 2:** Inverting and non-inverting amplifier configurations using op-amps.
 - Lecture 3:** Differential amplifier and common-mode rejection.
 - Lecture 4:** Instrumentation amplifier: concept and design basics.
 - Lecture 5:** Op-amp-based adder, subtractor, integrator, and differentiator.
 - Lecture 6:** Signal conditioning circuits – concept and applications.
 - Lecture 7:** Feedback amplifiers – types and their role in stability.
 - Lecture 8:** Power amplifiers – classification and working (Class A, B, AB, C).
 - Lecture 9:** Oscillator circuits using op-amps: Wien bridge, phase shift.
 - Lecture 10:** Recap and practice problems on amplifier circuits.
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UNIT 3: Digital Electronics (8 Lectures)

- Lecture 1:** Introduction to logic gates and Boolean algebra.
 - Lecture 2:** Combinational logic design – half adder, full adder, multiplexers.
 - Lecture 3:** Sequential circuits – flip-flops and shift registers.
 - Lecture 4:** Counters and timers: asynchronous and synchronous types.
 - Lecture 5:** Digital comparators and encoders/decoders.
 - Lecture 6:** A/D and D/A converters – working and types.
 - Lecture 7:** Basics of microprocessor and microcontroller architecture.
 - Lecture 8:** Instruction sets and simple programming overview.
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UNIT 4: Signal Processing, Communication & High-Frequency Devices (12 Lectures)

- Lecture 1:** Overview of analog vs. digital signal processing.
- Lecture 2:** Noise in electronic circuits – filtering and shielding techniques.
- Lecture 3:** Grounding and isolation in high-frequency systems.
- Lecture 4:** Fourier transforms – concept and applications in electronics.
- Lecture 5:** Modulation techniques – AM, FM basics and block diagrams.
- Lecture 6:** Demodulation and signal recovery.
- Lecture 7:** Generation of high-frequency signals – transistor oscillators.
- Lecture 8:** Tuned amplifiers – resonance and selectivity.
- Lecture 9:** Detectors – AM detector, envelope detector, superheterodyne.
- Lecture 10:** Power supply circuits and SMPS – working principle.
- Lecture 11:** Active filters – RC low-pass, high-pass, and band-pass filters.
- Lecture 12:** Recap and applications of electronic communication systems.

PHE502: Electronics Laboratory (LAB-I)

Total Credits: 04 (Credits: Theory:03, Tutorial:01)

Total Hours: Practical:120

L	T	P	Cr
0	0	4	4

Course Objective:

1. To provide the practical knowledge of experimental electronics.
2. Learn to acquire data in various experimental systems and to understand the use of various electronic systems.
3. To design a circuit on the bread-board for a particular experiment.
4. To keep the record of the experiments, performed in the laboratory.

Course Outcome:

S.No.	Course Outcome Statement	Bloom's Level(s)
CO1	Develop competency in handling electronic components and instruments for conducting experiments in electronics	B3(Apply)
CO2	Acquire and analyze data from various experimental setups using appropriate electronic systems and measurement techniques	B4(Analyze)
CO3	Design and implement basic electronic circuits on a breadboard based on given experimental objectives.	B6,B3(Create, Apply)
CO4	Maintain a clear and organized laboratory record documenting experimental procedures, results, and analysis.	B3, B5(Apply, Evaluate)

CO-PO Mapping Matrix of Functional Topics of Physics

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	✓		✓				
CO2	✓	✓	✓	✓			
CO3	✓	✓	✓	✓	✓		✓
CO4	✓	✓	✓	✓		✓	✓

Course Content:

- To study the various digital analog circuits:
4-bit discrete binary adder network, 8-bit DAC using 0808 IC without OP-amp.
- To draw transfer characteristics of
 - An OP-amp (741IC) in inverting mode in close loop.
 - To determine offset voltage
 - To determine CMRR of the OP-amp
- To determine the band gap of a semiconductor (Ge)
- To study the amplitude modulation with the help of CRO
 - with I/O frequency at constant I/O voltage
 - To study variation of percentage of modulation with I/O voltage at constant I/O frequency.
 - Plotting modulated and demodulated wave
 - To determine carrier frequency

5. To study the frequency response of RC coupled amplifier
 - (a) with feedback
 - (b) without feedback
6. To perform various mathematical, logical and jump operations for 8 bit numbers using 8085 microprocessor.
7. To perform various mathematical, logical operations and jump operations for 16 bit numbers using 8085 microprocessors.
8. To study a RC circuit as a low pass and high pass filter and study the RC circuit as a differentiator and integrator.

Lecture Plan: Electronics Laboratory (LAB-I)

Lecture1: Familiarity with lab equipment, safety norms, lab record format

Lecture2: Understand digital addition and logic gates

Lecture3: Study of digital-to-analog conversion

Lecture4: Analyze gain and behavior in closed loop

Lecture5: Measure input offset in practical circuits

Lecture6: Test amplifier rejection of common-mode signals

Lecture7: Determine energy gap via V-I curve

Lecture8: Assess understanding of op-amp and basic circuits

Lecture9: Study of waveform under fixed amplitude

Lecture10: Observe how modulation index varies

Lecture11: Visualization and waveform analysis

Lecture12: Carrier analysis using signal tracing

Lecture13: Group discussion and error analysis

Lecture14: Study amplifier response and gain

Lecture15: Analyze changes in bandwidth and stability

Lecture16: Discuss impact of feedback on gain and distortion

Lecture17: Structure, programming model, machine cycle

Lecture18: Write and run programs for 8-bit math/logic

Lecture19: Learn control flow and conditional logic

Lecture20: Perform extended 16-bit operations

Lecture21: Study RC circuit as differentiator and integrator

Lecture22: Debug and optimize code with test inputs

Lecture23: Complete all pending entries, viva prep

Lecture24: Full assessment of practical knowledge



